CHAPTER 5

WARM AIR HEATING

Section I. DESCRIPTION OF EQUIPMENT

5-1. Methods

Warm air heating methods include all those in which air is first heated by passing it over heat transfer surfaces warmed by the direct combustion of fuel and then circulated to the space to be heated. This may be done by space heaters which are located directly in the occupied space, pipeless furnaces which are located outside the heated space but deliver warm air through a single register, and gravity or forced-warm-air furnaces which are located outside the heated space and distribute air through a duct system to the various spaces to be heated. Indirect warm air systems in which air is first heated by a steam or hot water coil and then distributed through a duct system may also be included in this group.

5-2. Space Heaters

Space heaters are designed to burn either coal, oil, or gas but seldom more than one of these fuels. Coal-fired space heaters are constructed either entirely of cast iron or of steel with cast iron or ceramic combustion chambers. Oil and gas space heaters are usually manufactured with steel combustion chambers. The three types of coal-fired space heaters in use by the U.S. Army are shown in figures 5-1, 5-2, and 5-3. These heaters are shipped completely assembled except for a few small parts. Installation is simple. They are hand fired and, when proper firing methods are followed, require little attention. For further details on these and other space heaters see TM 5-646. A typical oil-fired space heater is shown in figure 5-4. This heater is equipped with an air-circulating fan, though many heaters do not have this feature. These heaters use vaporizing type burners and require a light grade of fuel oil, Federal Specification No. 1, for satisfactory operation. Each heater has its own fuel tank but may be connected to a larger outside tank if desired. Oil fuel flow and rate of heating may be regulated either manually or automatically through use of a room thermostat. Gas-fired space heaters are manufactured in several types, including one similar to the oil-fired heater shown in figure 5-4. They are usually equipped with safety pilots to insure ignition when the main burner is turned on. The main burner may be controlled either manually or automatically. A panel type gas space heater is shown in figure 5-5. This heater may be recessed in either an inside or outside wall with the vent, properly insulated, run up through the wall. These heaters have the advantage of requiring less floor space. Because space heaters are located within occupied spaces, hazards attending the leakage of flue gases into the living space are always present, and care must be taken to be certain that all flue-pipe joints are tight and secured with one or more sheet metal screws. This hazard has been eliminated in the design shown in figure 5-6. This heater is for installation in outside walls only and includes an integral air supply and vent which takes combustion air from, and exhausts flue gases to, the outdoors. There is no opening whatsoever between the interior of the combustion chamber and the space to be heated.

5-3. Pipeless Furnaces

A pipeless furnace is one designed to be installed below the floor of the space to be heated. It is connected so as to deliver warm air to the space above through a single register in the floor. Cold air also returns to the furnace along the outer edge of this same register, passes

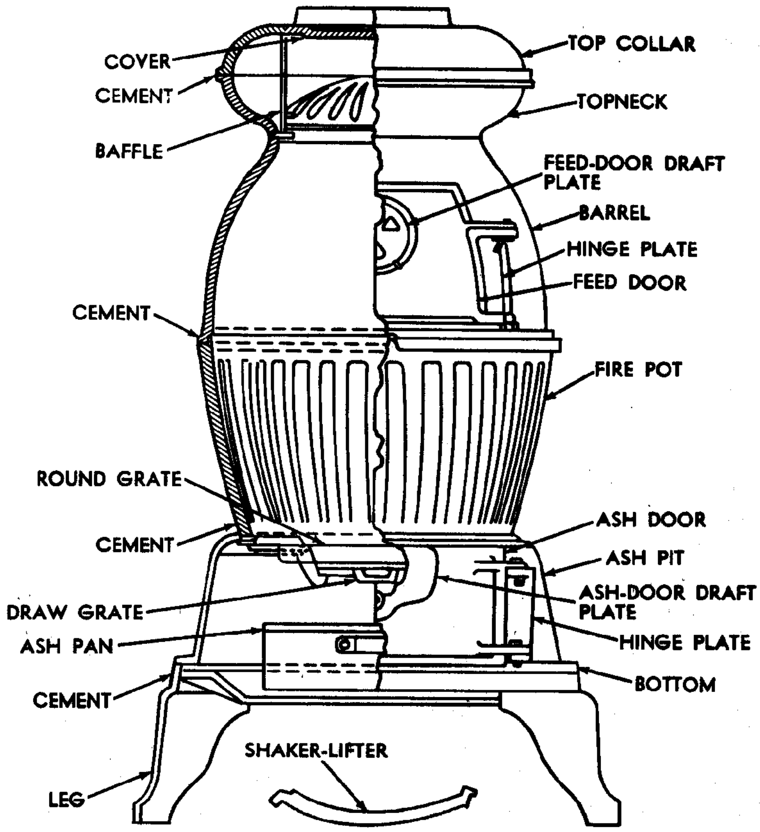


Figure 5-1. Cannon stove.

down through an air chamber surrounding the furnace, and is reheated. An advantage of this furnace is that it is designed to be hung from the floor of the space it serves and can be installed where there is only a few feet of head room below the space to be heated. It may be designed for gas firing (fig. 5-7) or oil firing (fig. 5-8).

5-4. Gravity Warm-Air Furnaces

Gravity warm-air furnaces distribute heated air through ducts to serve individual rooms. As air is heated in the furnace it expands and becomes lighter than the cooler air returning to the furnace. It rises and passes through the ducts which are connected to the top of the furnace. These ducts are usually made of round pipe. They must rise continuously from the furnace to the warm-air register from which the air is delivered into the heated space. Gravity warm-air furnaces may be constructed of either cast iron or steel. Cast iron furnaces are constructed in sections which are made gastight by the use of asbestos-rope packing and furnace cement. They usually include a secondary heating chamber or radiator which is formed in the shape of a hollow doughnut and mounted on top of the furnace (fig. 5-9). Steel furnaces are made of heavy gage steel with a firebrick lining in the combustion chamber. They also have one or more secondary heat exchangers which are located at the back or side, or may entirely surround the furnace proper. They may be designed to burn all fuels.

5-5. Forced-Warm-Air Furnaces

a. The majority of furnaces produced today are of the forced-warm-air type. This type of furnace includes the elements of a gravity warm-air-furnace plus a fan to insure adequate

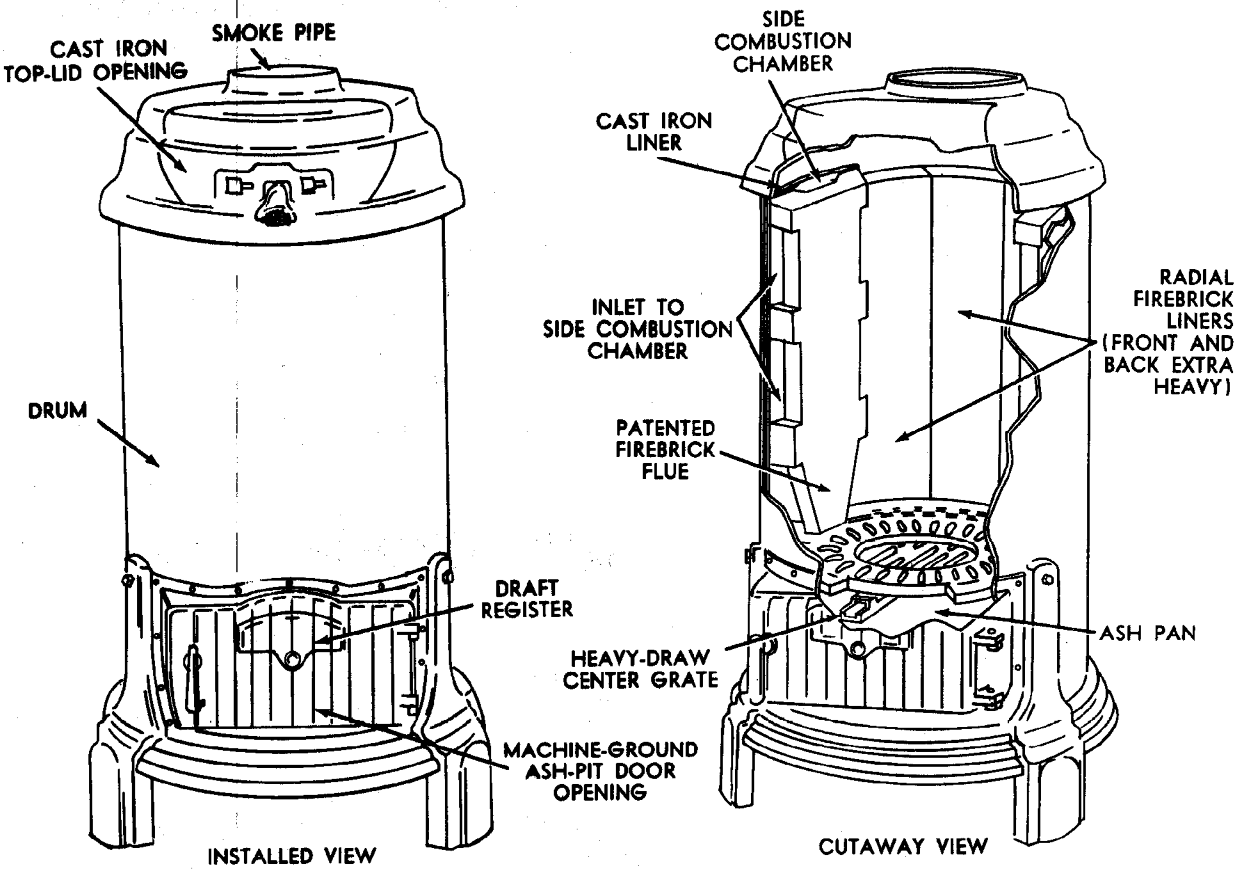
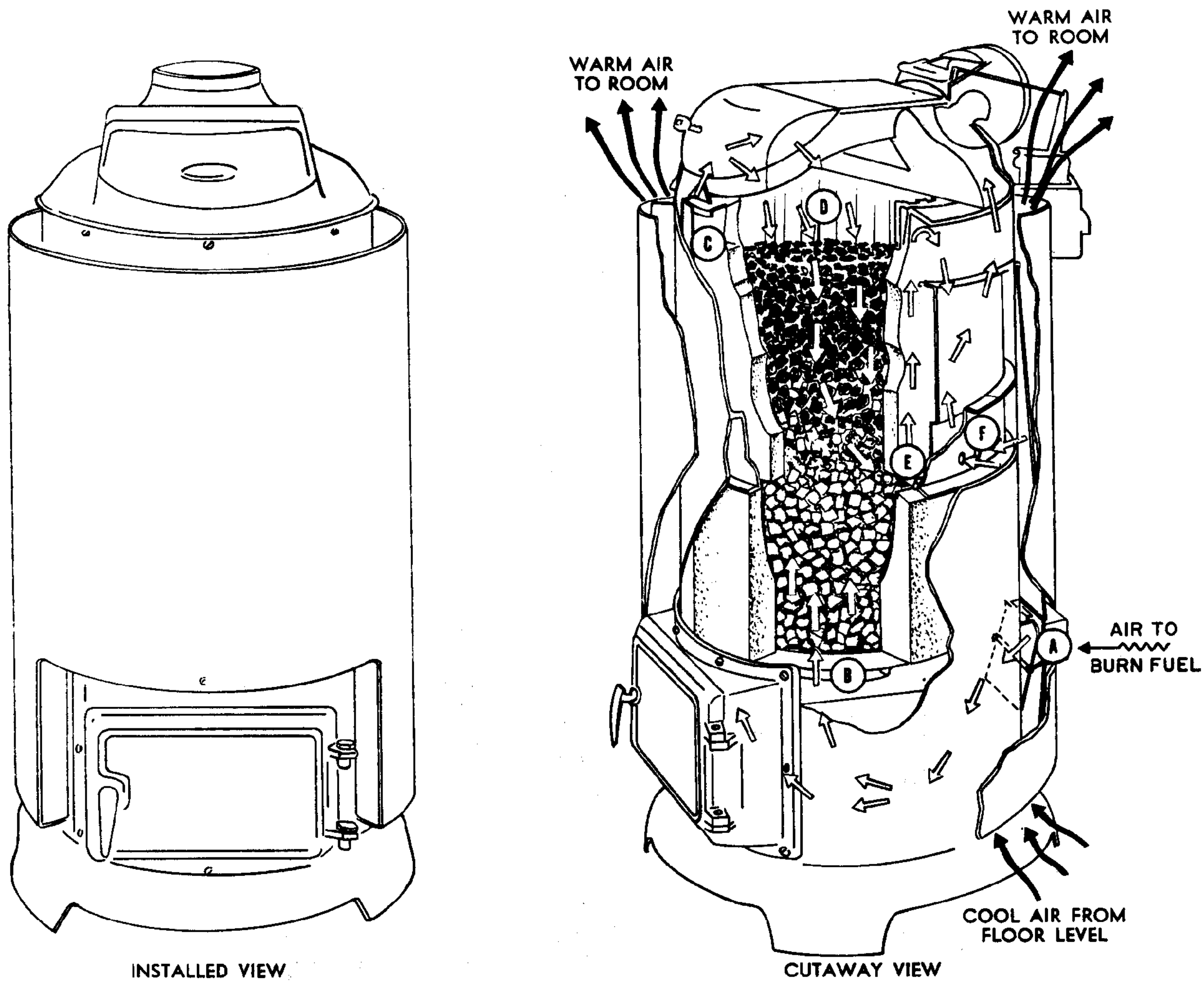


Figure 5-2. U.S. Army No. 1 space heater.

air distribution. It may also include filters to provide air filtration and a humidifier to add moisture. The inclusion of a positive pressure fan makes possible the use of smaller ducts and the extension of the system to heat larger areas without the need of sloping the air ducts. It is possible to heat rooms located on floors below the furnace if necessary. Forced-warm-air furnaces are manufactured in a variety of designs. A typical oil-fired warm-air furnace is shown in figure 5-10. A gas-fired horizontal type furnace is shown in figure 5-11. This furnace, which requires little space, is designed for installation above the ceiling or for hanging below the floor of the space that is to be heated. Though it occupies little space it should be located so that proper access for servicing is provided. A gas-fired vertical-furnace is shown in figure 5-12. This type of furnace is frequently installed on the same level as the space it serves. Warm air is discharged vertically from the top, and return air ducts may be brought in horizontally near the bottom of the furnace or upward through the floor into the fan compartment. A special type of gas furnace, known as a duct furnace, is manufactured for mounting in a duct system where air circulation is provided by an external fan. This fan may be part of a cooling unit providing summer air conditioning. For information and precautions in the use of duct furnaces see TM 5-642.

b. Humidifiers installed with warm-air furnaces are usually of the pan type shown in figure 5-13. Unless the water used is relatively free of solids, these humidifiers require frequent attention since the float may stick in the open position or the valve may clog. Overflowing of the pan may result in a cracked heating



A Air for combustion enters at control damper
B Combustion begins at grate level
C Tube carries some air for combustion to top of heater
D Downdraft of air carries partially burned gases to E
E Combustion is completed with help of air entering holes at F
F Air holes

Figure 5-3. U.S. Army No. 4 space heater.

section, and a stopped-up inlet valve will make the humidifier inoperative. Other types of humidifiers in small systems are:

(1) *Mechanical breakup of the water* (fig. 5-14.) This type uses a spinning disc to throw the water through a perforated piece of metal called a comb. This breaks the water into fine droplets. The atomized water is then drawn into the duct system because of the difference in static pressure between the outside atmosphere and the pressure in the duct the humidifier is mounted on. This type of humidifier must always be mounted on the return air part of the duct system.

(2) *Evaporation from carrying medium* (fig. 5-15). This type humidifier uses an evaporation pad in the shape of a wheel. The slowly turning wheel is submerged in the water in the lower pan where the sponge-like plastic foam material becomes saturated with water. The wheel lifts this portion of the pad and exposes it to the warm dry air flowing through it. Air

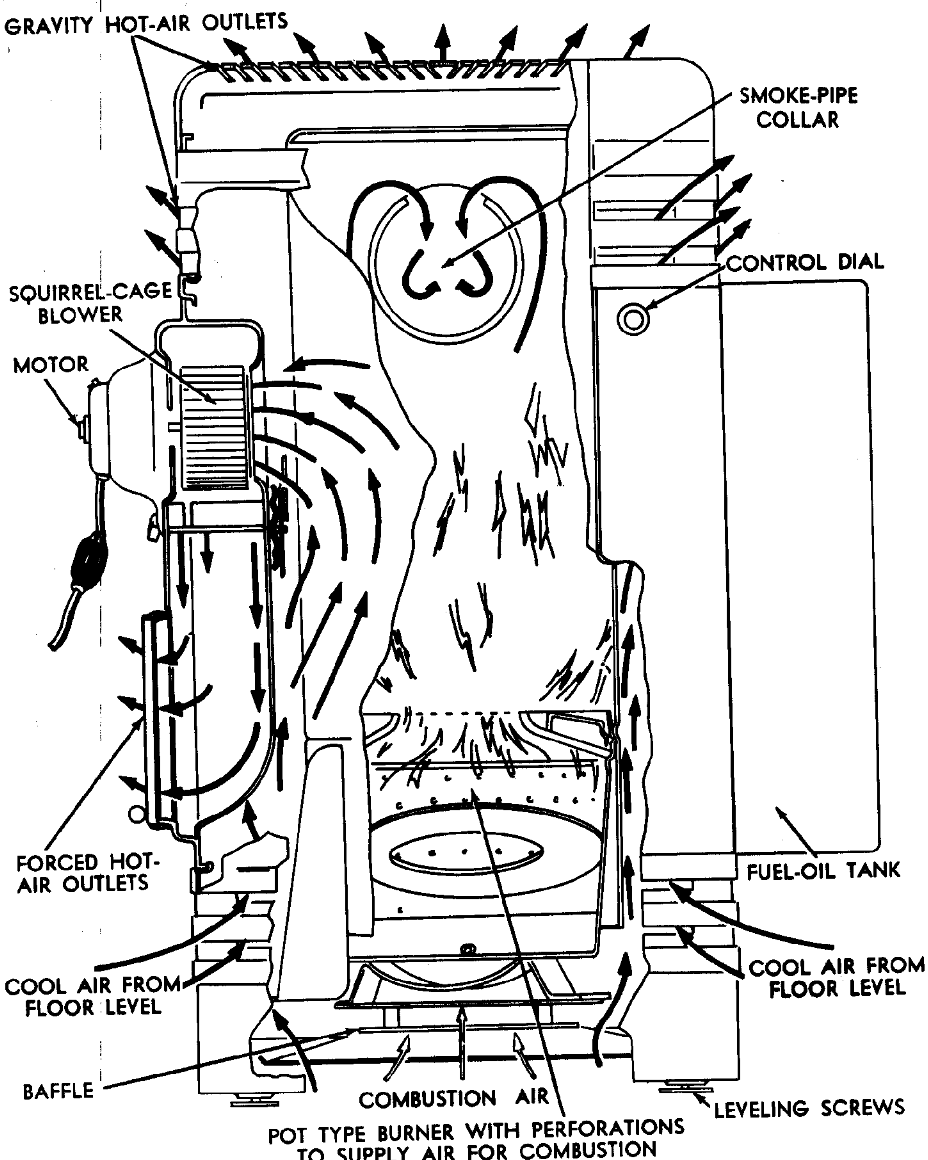


Figure 5-4. Oil-fired space heater

flow through the humidifier is from the warm air supply plenum, through the humidifier and into the return air plenum (fig. 5-16). The warm dry air from the supply air system will absorb more moisture because of lower relative humidity at the higher temperatures. The pressure difference between the positive static pressure in the supply plenum and the negative supply pressure in the return air plenum gives good air flow through the humidifier for complete and rapid moisture pickup.

(3) *Positive evaporating type* (fig. 5-17). This type humidifier uses its own source of heat to evaporate the water. It is not dependent on the use of heated air to accomplish this evaporation. It has an advantage over the mechanical type in that the water evaporation leaves all minerals and impurities in the water behind in

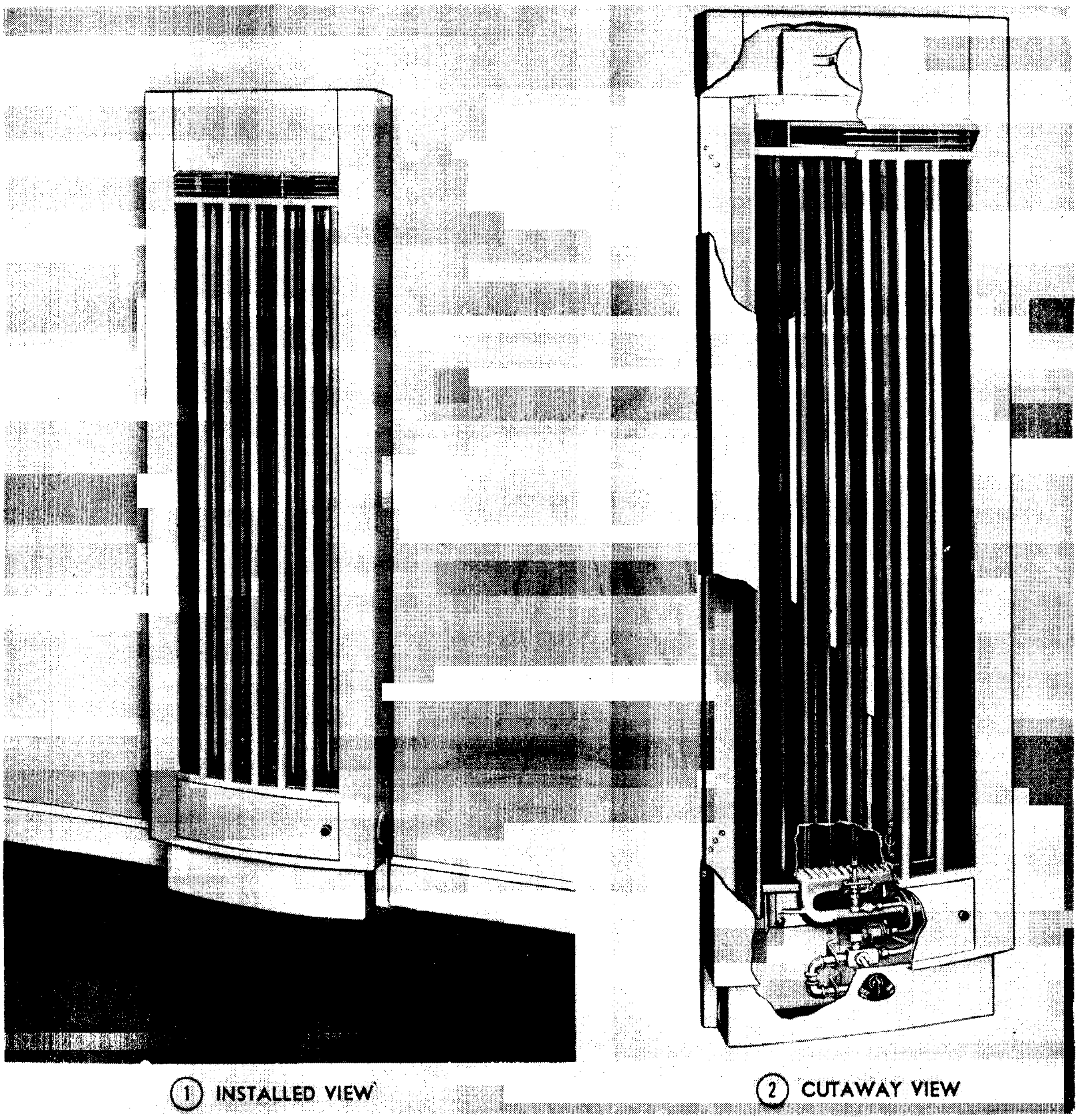


Figure 5-5. Gas-fired panel type space heater.

the pan for periodic disposal. The advantage of the positive evaporating type over the rotating pad type is that it does not require a flow of heated air through it. Therefore, it can be connected into either the supply or return duct system without consideration of a duct connection to the other side of the system.

5-6. Air Ducts

Air ducts for use with warm air systems are usually made of sheet metal. Gravity systems generally employ prefabricated round pipe and fittings (fig. 5-18). Heated air is taken from the top or "bonnet" of the furnace through basement pipe or "leaders" (fig. 5-19) to vertical

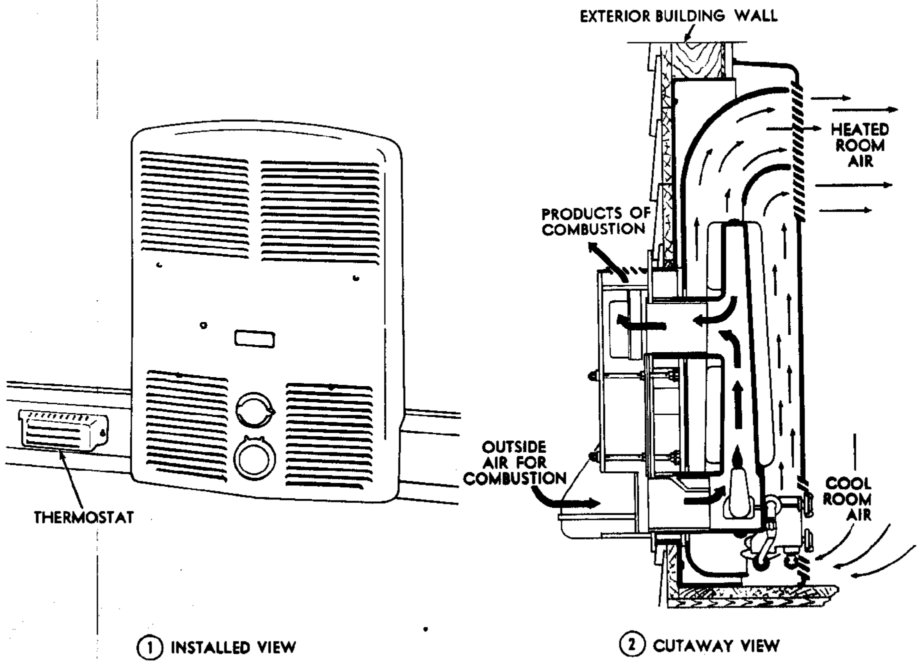
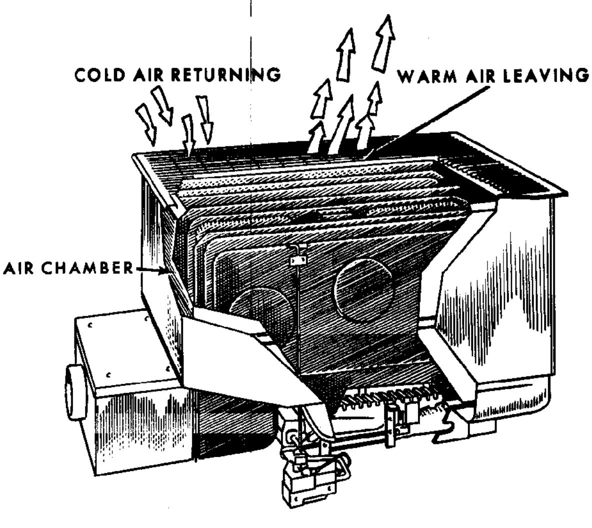


Figure 5-6. Panel type space heater with integrat vent.



1 Inner casing
2 Heat exchanger
3 Outer casing
4 High temperature limit control
5 Fuel control valve
6 Oil burner
7 Bottom

Figure 5-7. Gas-fired pipeless furnace.

warm-air pipes inside partitions called "stacks" or "risers." Air is discharged through registers set in register boxes placed either in the floor or the side wall near the baseboard. Forced-warm-air systems usually employ rectangular ducts and fittings (fig. 5-20). These ducts and fittings may be mass produced in standard sizes or custom-made for each job. Methods of system design are given in paragraphs 5-8 through 5-10. The design and fabrication of sheet metal ducts and fittings are covered in chapters 10 and 11. Prefabricated ducts and fittings made of fiberglass are sometimes used. Air passages forming parts of the duct system may also be included in the building construction or may be constructed on the job from other material. However, when this is done, the construction must be fireproof and substantially airtight.

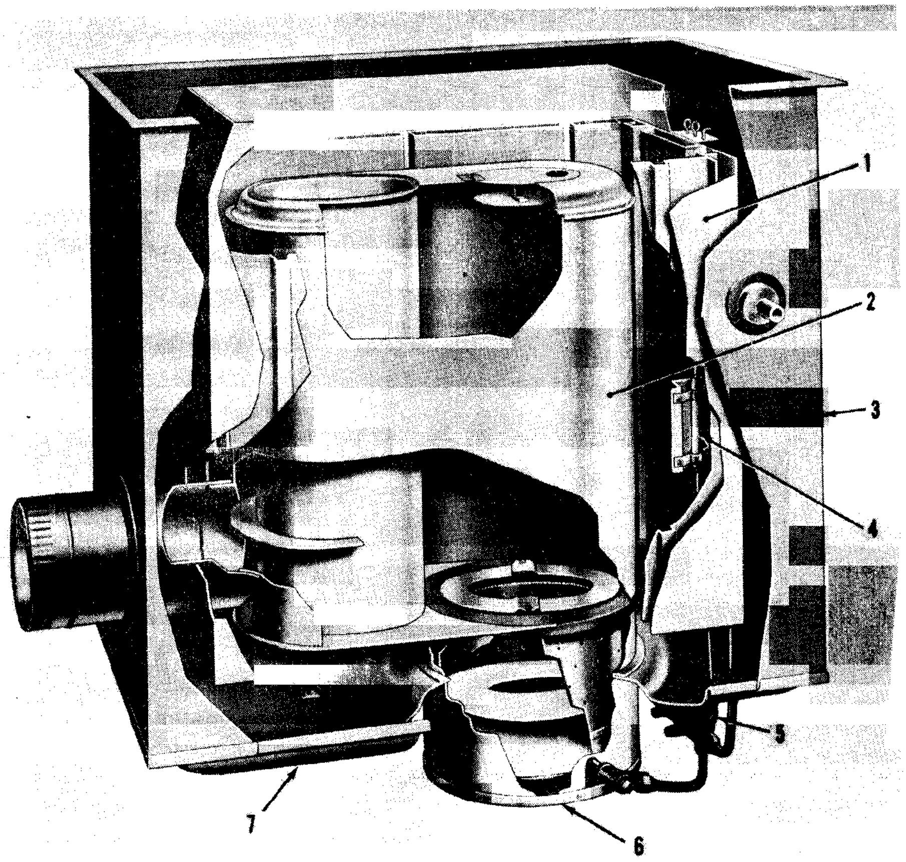


Figure 5-8. Oil-fired floor furnace.

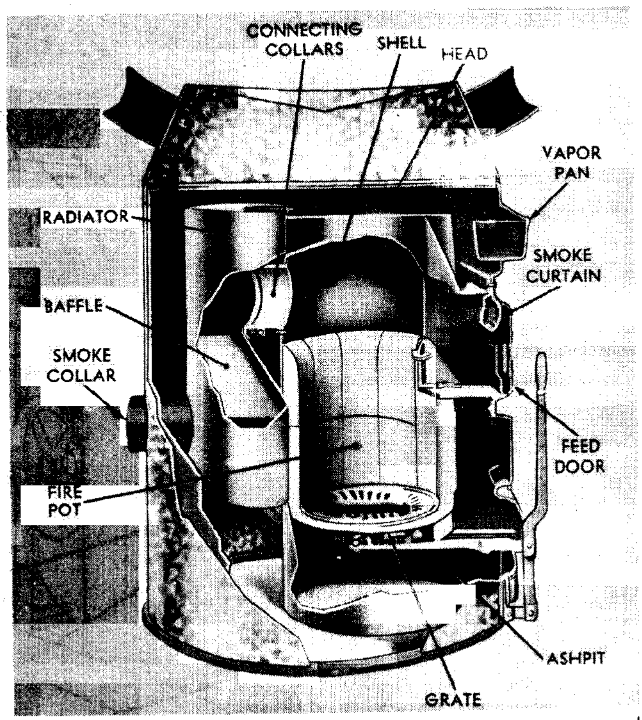
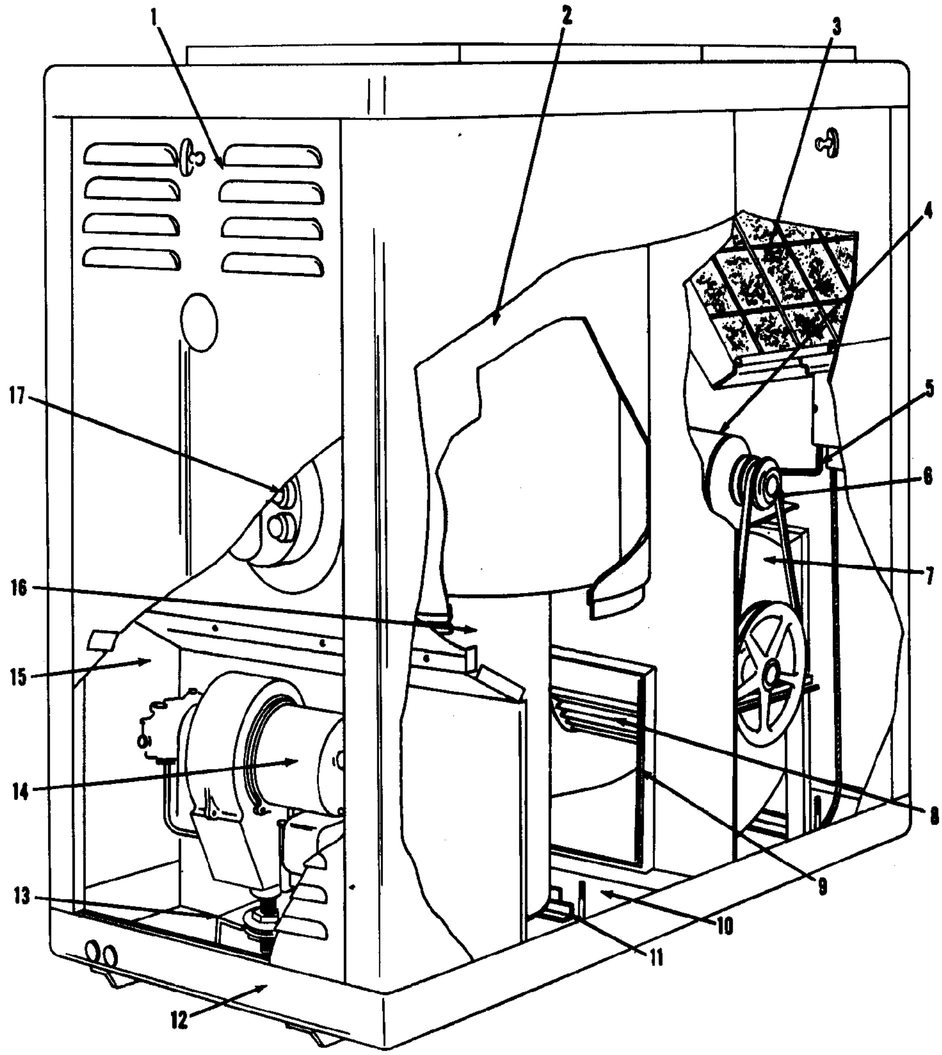


Figure 5-9. Coal-fired gravity warm-air furnace.



1	Cabinet	10	Airtight steel floor
2	Baffle liner	11	Combustion-chamber mounting
3	Filters	12	Base
4	Motor	13	Oil burner base
5	Electric wiring (underwriter's approved)	14	Oil burner
6	Adjustable-speed pulley	15	Burner compartment
7	Blower	16	Radiating surface
8	Blower wheel	17	Flame observation door
9	Asbestos-cloth seal		

Figure 5-10. Oil-fired warm-air furnace.

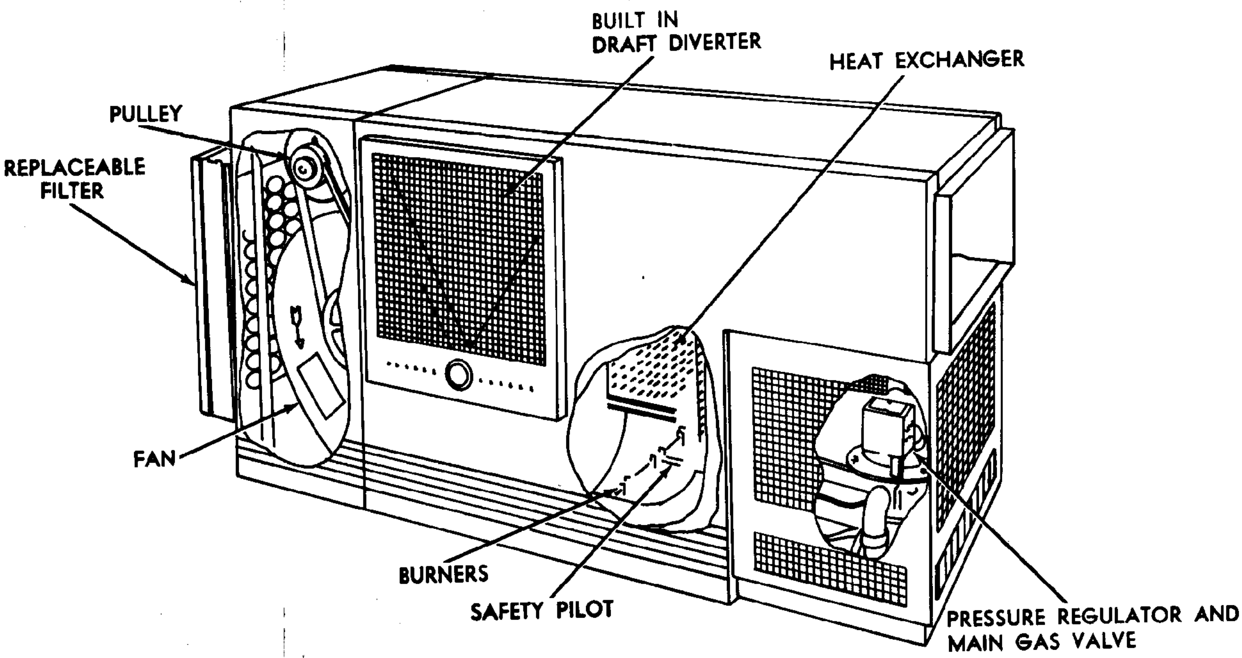


Figure 5-11. Gas-fired horizontal warm-air furnace.

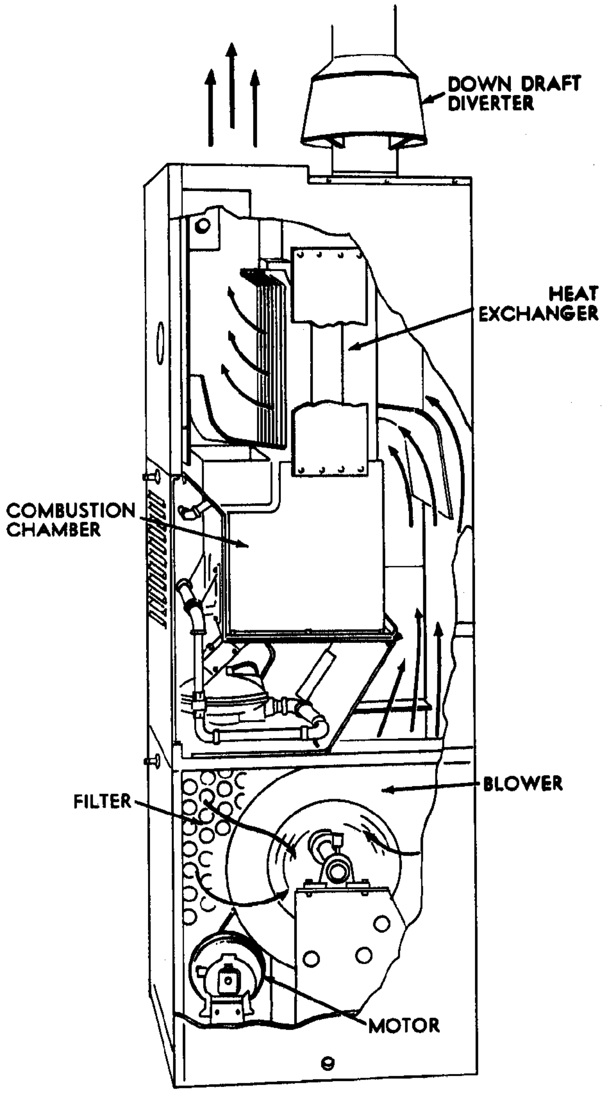


Figure 5-12. Gas-fired vertical warm-air furnace.

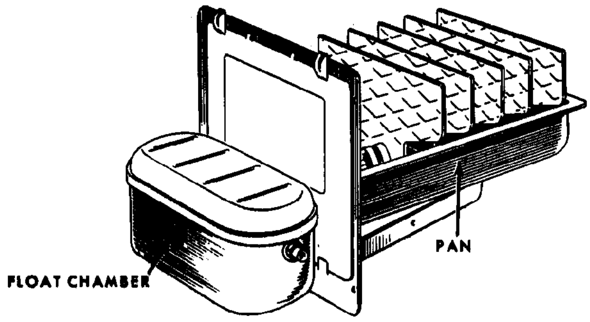


Figure 5-13. Pan type humidifier.

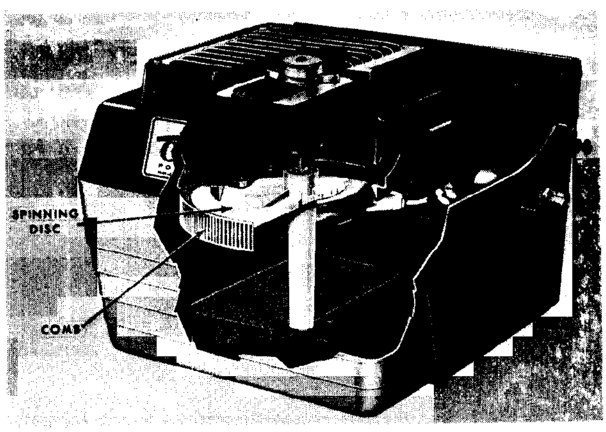


Figure 5-14. Humidifier with spinning disc.

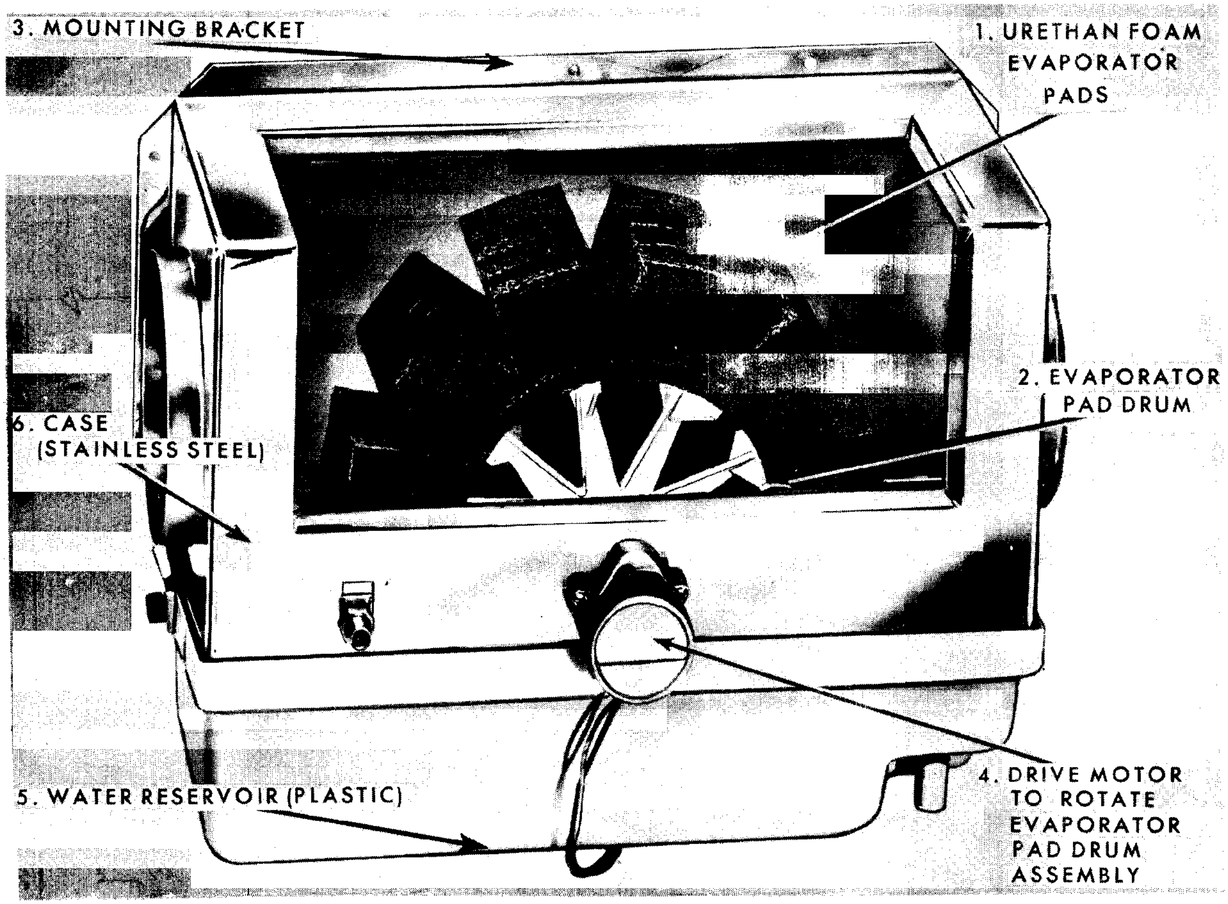


Figure 5-15. Humidifier with evaporation pad.

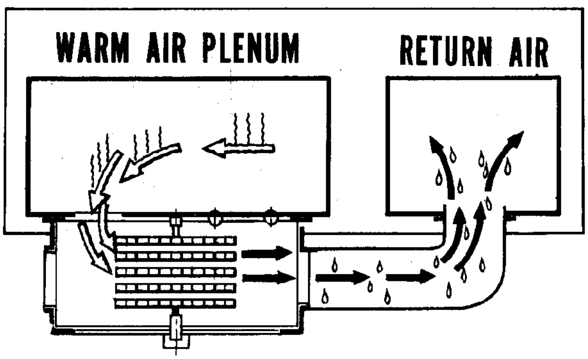


Figure 5-16. Air flow through humidifier.

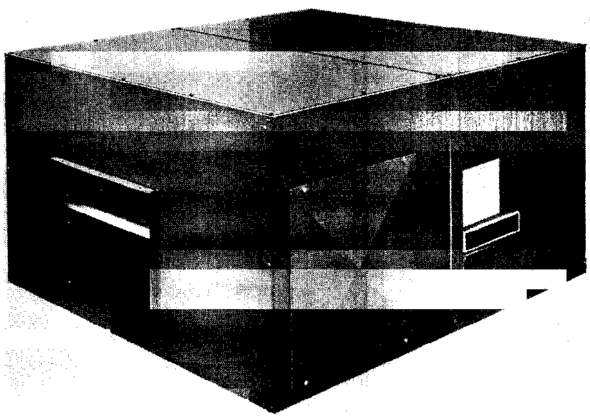
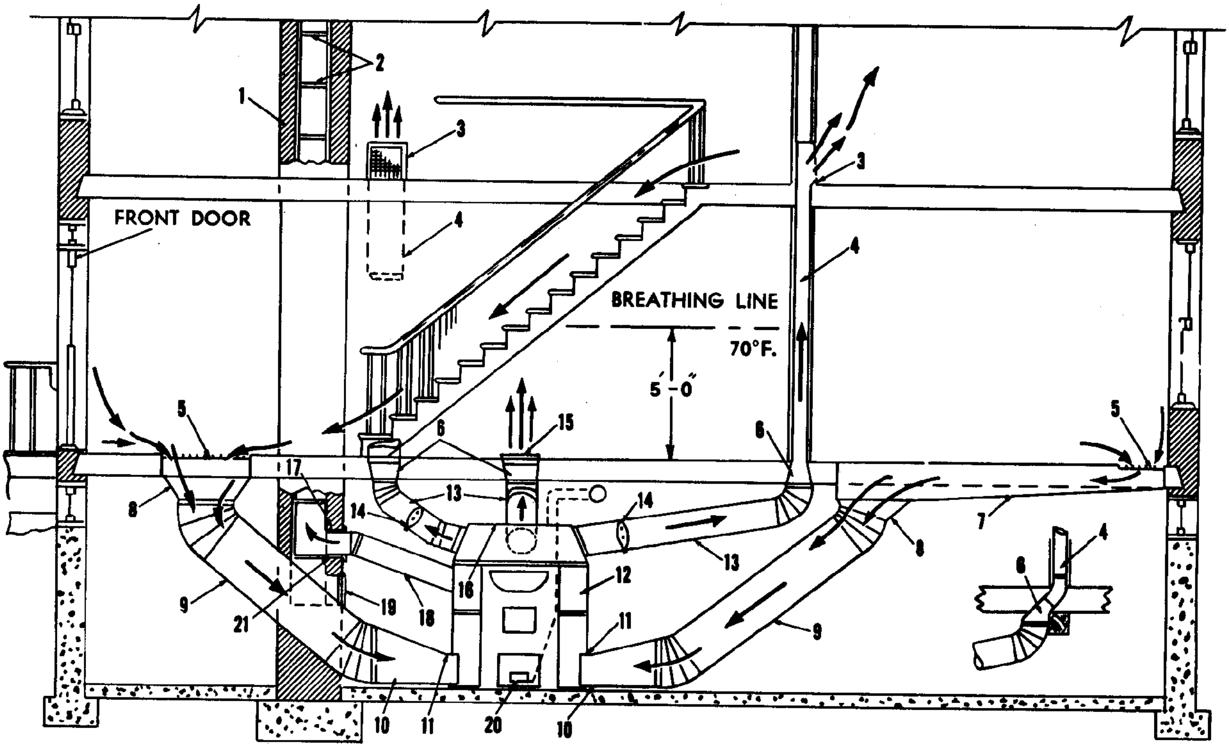


Figure 5-17. Positive evaporating type humidifier.



1 At least 8-inch brick
2 All joints airtight
3 Baseboard register
4 Rectangular wall stack
5 Return air face
6 Transition fittings
7 Panning under joists
8 Transition collar
9 Round return pipe
10 Transition shoe
11 Top of shoe at casing should not be above grate level
12 Casing body
13 Round leader, use pitch 1-inch per foot
14 Dampers in all leaders except one
15 Floor register
16 Casing hood or bonnet. Top of all leader collars
17 No other connection beside that to furnace
18 Smoke pipe, end flush with inner surface of flue
19 Cleanout frame and door, airtight
20 Draft door
21 Provide terra cotta flue thimble where smoke pipe enters chimney

Figure 5-18. Gravity air heating system, showing good installation practice.

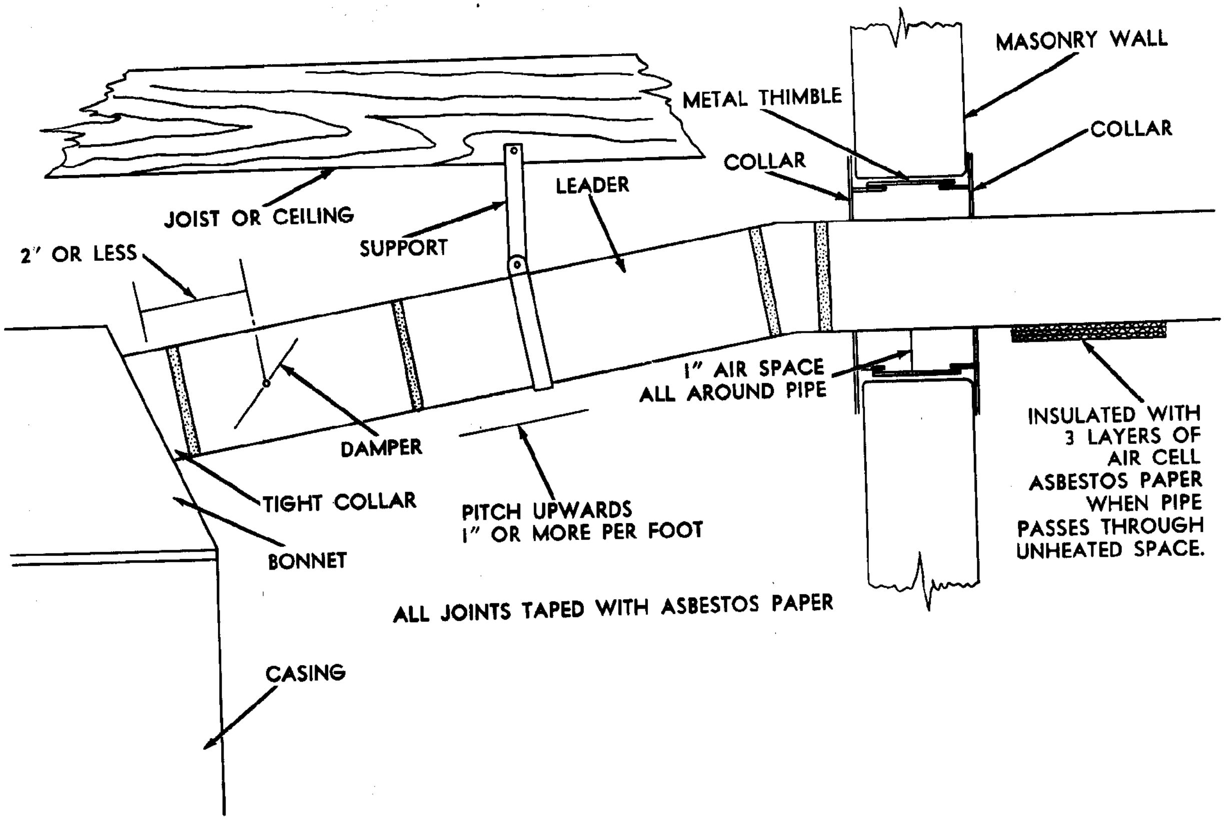


Figure 5-19. Bonnet connections of gravity warm-air furnace.

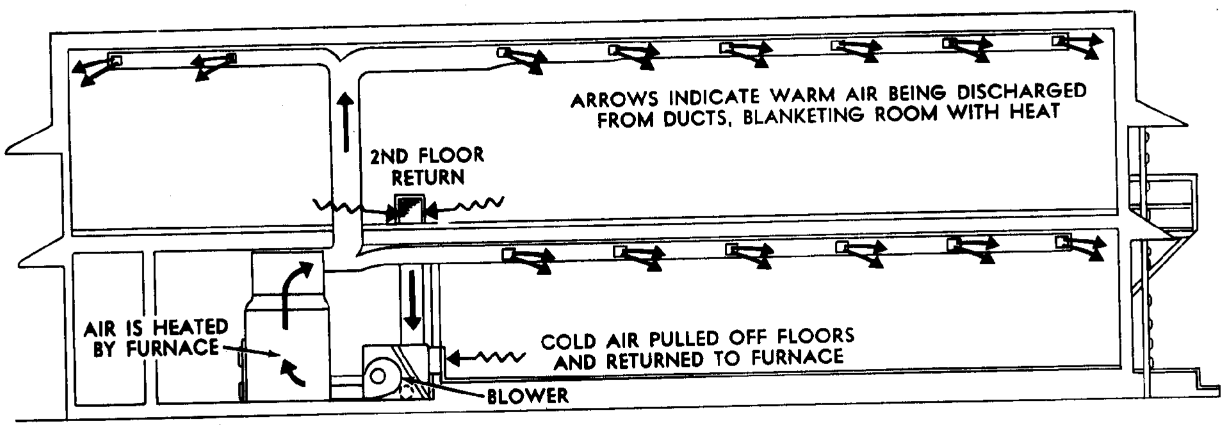


Figure 5-20. Forced-air heating system.

Section II. DESIGN OF WARM AIR SYSTEMS

5-7. Sizing of Equipment

Warm air furnaces are rated by the National Warm Air Heating and Air Conditioning Association, if coal- or oil-fired, and by the American Gas Association if gas-fired. These ratings are available from furnace manufacturers and in the publications of the associations named. Because the duct system and the air within it has much less heat capacity than the water and piping of steam or hot water system, warm air systems need no allowance for pickup in the selection of furnace capacity. Piping losses can be taken at zero for space heaters located in the space to be heated, 10 percent for warm air systems using insulated supply duct, or 15 percent or more for warm air systems with supply ducts bare. Space heaters should be selected with a heat output rating equal to or greater than the heat loss of the space served, and warm air furnaces should be chosen with a heat output 10 or 15 percent greater than the direct requirement for the space served.

5-8. Air Distribution

Satisfactory heating from warm air systems is absolutely dependent on the proper distribution of warm air from the heating appliance to all portions of the space served. Warm air must be distributed in the quantities required to offset the rate of heat loss of each heated space, or temperature differences between rooms will occur. This differs somewhat from radiator systems where the size of the radiators is the most important factor in determining the rate of heat released to each room. With radiator systems, distribution is primarily a problem of getting enough hot water or steam to each radiator to be sure that the radiator heats to its rated capacity. It is not possible to deliver more heat through steam or hot water than the radiator is designed to transmit. With warm air systems, however, the amount of heat reaching each room is determined by the rate of air delivery to that room so that temperature balance is entirely a problem of control of air distribution. In addition, the natural tendency of warm air to rise and cold air to fall within the heated space must be recognized. Air supply and return openings should be located with a view to eliminating air stratification and cold floors. In general, warm air registers should be located so as to deliver air to or along the areas of greatest heat loss, and return grilles should be located where they will pick up cold air before it can spread to cause objectionable drafts.

5-9. Location of Equipment

a. Space Heaters and Pipeless Furnaces. Most of the heat given off by space heaters and all the heat output of pipeless furnaces and floor furnaces is transmitted by convection of warm air. In each case this warm air rises from the space heater or floor grille until it reaches the ceiling where it spreads out to surrounding walls and then moves downward to the floor. Temperatures are higher at the ceiling and fall off as the horizontal distance from the heater or grille increases. These devices should therefore be located as close to the center of the space to be heated as is practicable. Where more than one room is to be served by a furnace, the grille can be located in the floor of hallways or connecting doorways between rooms. Doors should be left open or removed and archways which restrict air passage should be removed if possible. Where more than one heater is used, the space should be divided evenly between the heaters. Where the rate of heat loss is disproportionately high in one portion of the space to be heated, that area should be favored in the location of the heater (fig. 5-21). Air stratification and drafts from cool air moving across the floor towards the heaters are sometimes a problem with this equipment. With pipeless or floor furnaces this condition may be somewhat improved by installing cold air return grilles under windows or other sources of cold air and connecting the grilles by ducts to the base of the furnace. Drafts are also accentuated if infiltration around windows or doors is high. Use of weather stripping can prevent this.

b. Gravity and Forced-Warm-Air Furnaces. Although air distribution with these duct type warm-air systems is much more positive, it is still desirable to locate gravity and forced-warm-air furnaces as close to the center of the

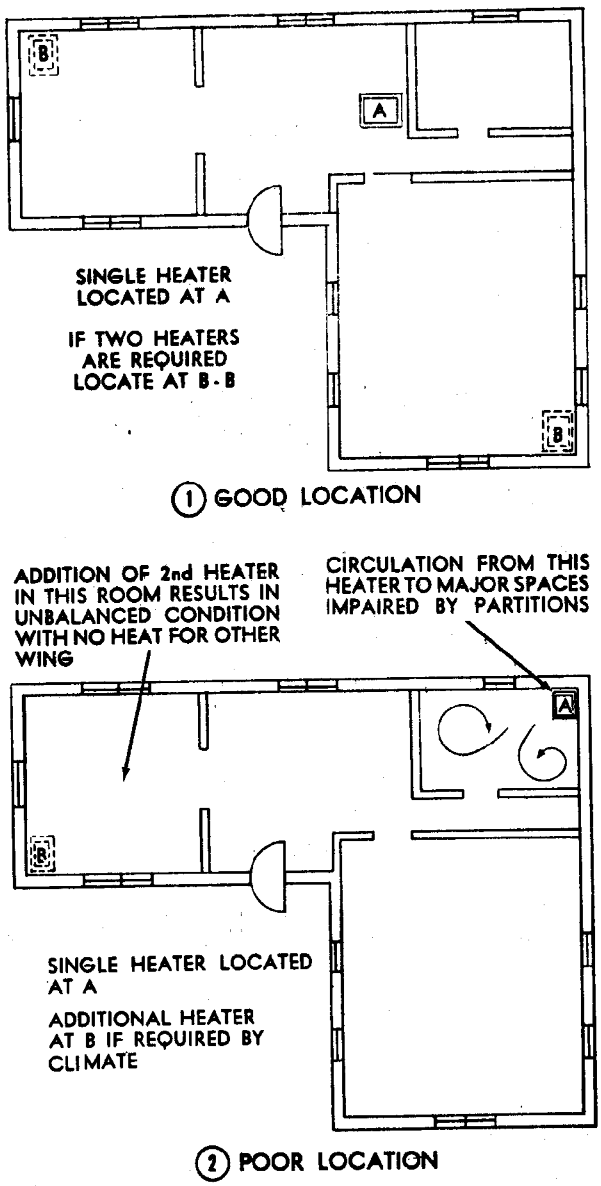


Figure 5-21. Space heater location.

area which they serve as possible. Rooms served by short ducts close to the furnaces will always tend to get more than their share of the heat, particularly during short firing periods in mild weather. Anything that can be done to equalize the length of ducts to various rooms will aid in the balancing of room temperatures.

5-10. Air Duct Layout

a. Gravity Systems. Warm air is discharged into rooms through openings called registers which are set in register boxes placed either in the floor or in an inside partition close to the floor. These registers are usually kept close to the inside wall although where there are areas of concentrated heat loss, such as a large window, a register may be placed adjacent to or below the window to overcome this loss at its source. The air supply to the furnace usually is returned from inside the building through one or more ducts (fig. 5-22) except that, where ventilation requirements are high and the building is tight, some or all of the air may be taken from outside. Required register riser and leader sizes are dependent on the heat delivery required, the length of the duct run, and the number and type of fittings in the run. The equivalent length of typical gravity warm air duct fittings, called "boots," are given in table L-1. To simplify design of gravity systems, standard sizes of pipe grilles and fittings have been arranged in related groups and given combination numbers. The sizes making up these combinations and their heat carrying capacities for equivalent duct lengths are given in tables L-2 thru L-7. Using these tables a gravity warm air system may be designed as follows:

(1) Calculate the heat loss of each room (paras 2-2 through 2-10);

(2) Prepare a layout as in figure 5-23 showing:

(*a*) The furnace.

(*b*) The chimney connection.

(*c*) Warm air registers (indicate whether floor or baseboard).

(*d*) Return air grilles.

(3) Indicate on each warm air leader:

(*a*) Whether it serves a first or second story room.

(*b*) The approximate length of the horizontal leader.

(*c*) The number of equivalent elbows required.

(4) Show the number and location of the return air grille and the path of the return air system. From the appropriate table in appendix L select the combination number which will give the heating requirements for each

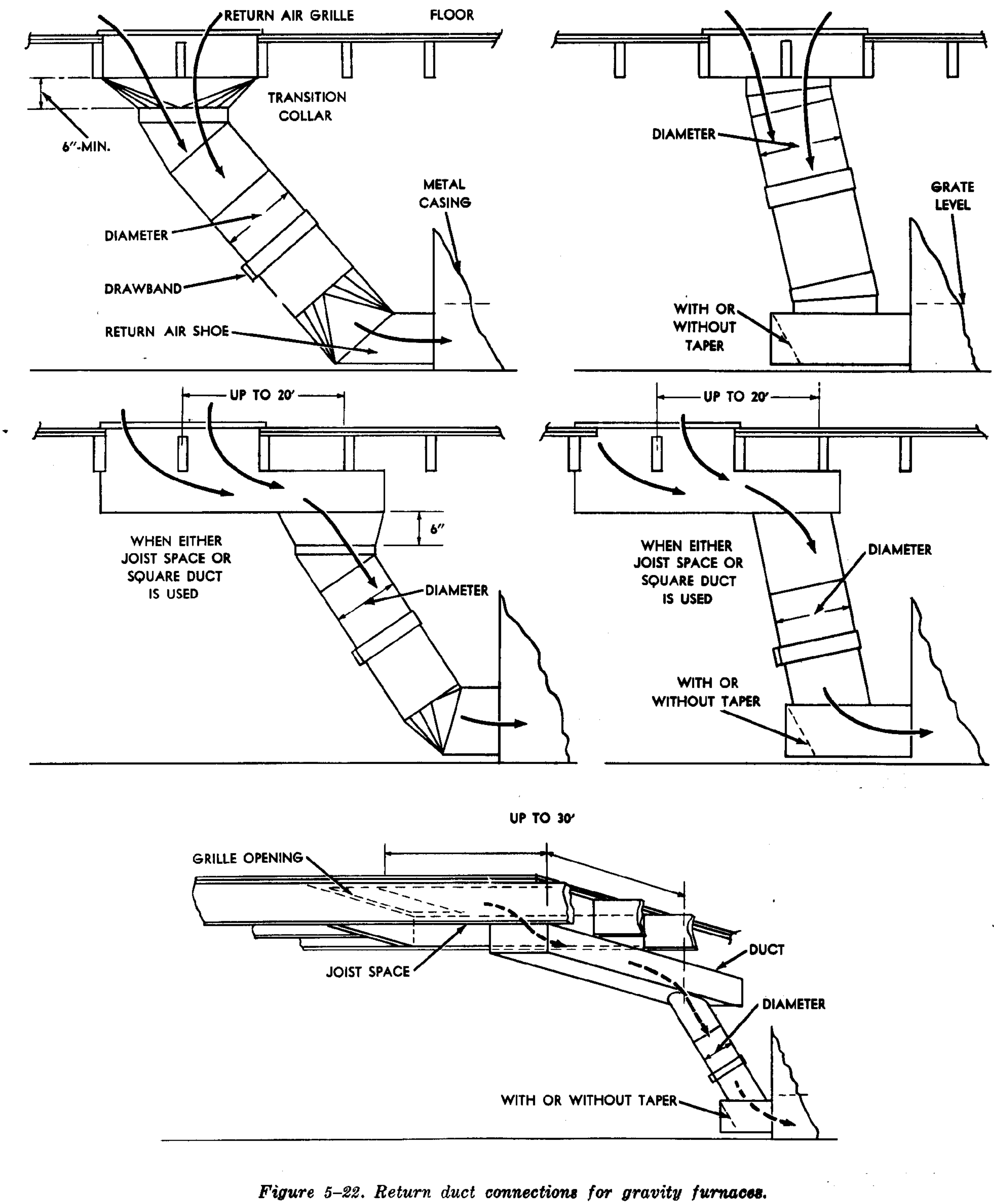


Figure 5-22. Return duct connections for gravity furnaces.

room. Then, using the combination number as found, read directly from the table the leader stack and register sizes required.

(5) From the tables in appendix L select the combination number for the return grille. Then select the duct and grille sizes corresponding to these numbers.

b. Forced Air Systems. Air supply registers for forced-warm-air systems are best located so that the air will be thrown to or along the sources of greatest heat loss. Location on interior partitions near outside walls is good, as is location on outside walls. Registers preferably should be located beneath windows if low discharge velocities are used or if diffusing type registers are used. This will keep the warm air close to the wall (fig. 5-24). Where floors are located over unheated spaces, it is well to place the registers as close to the floor as possible and to use deflecting vanes which spread the air downwards over the floor. This will help keep the floor warm. Return grille locations are not critical. They may be installed high or low, in ceilings, walls, or floors. They need not be installed in all rooms as long as they are of adequate size and all air supplied has a free path to circulate back to a return grille. The

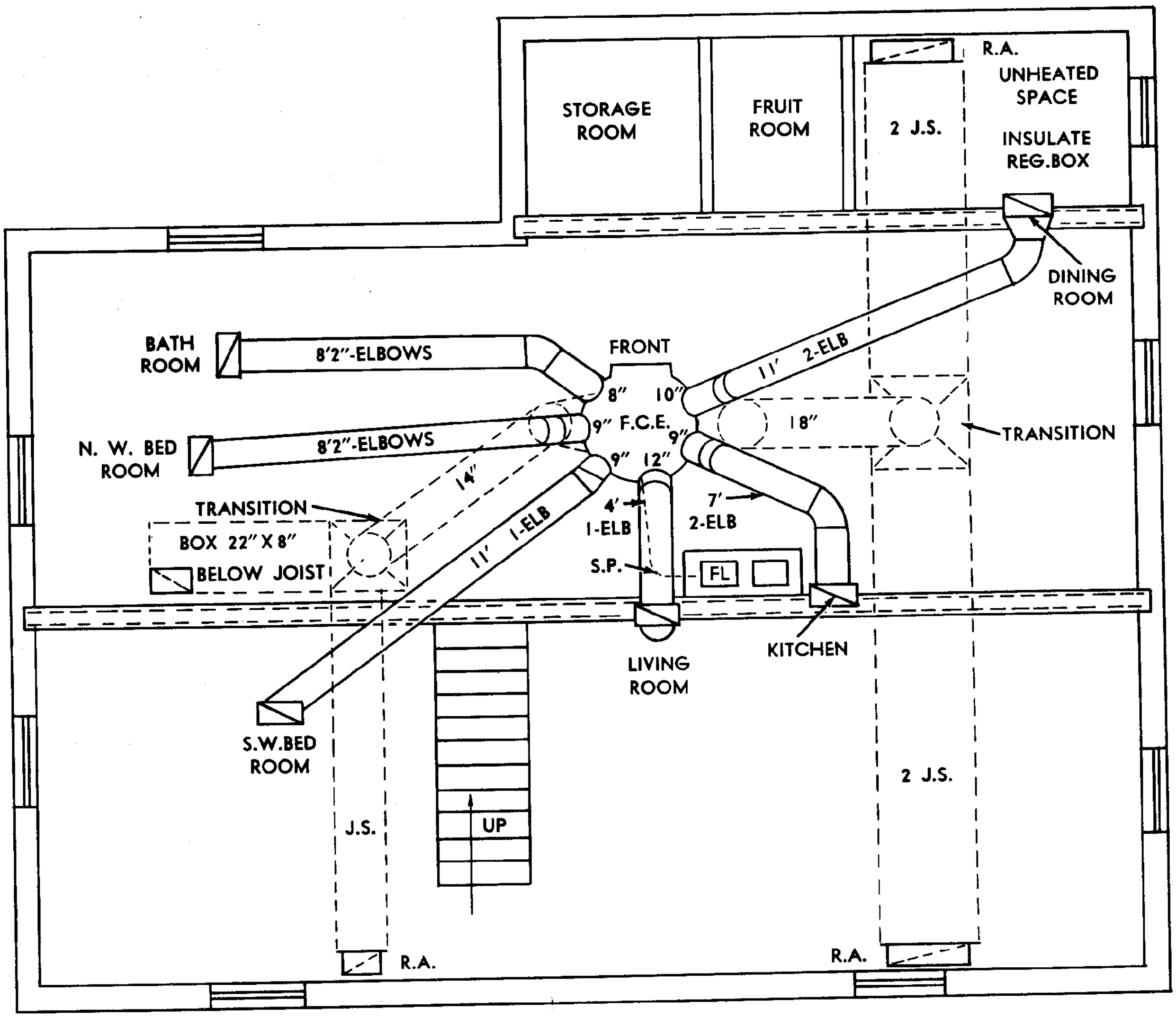


Figure 5-23. Layout of typical gravity warm-air system.

selection of register sizes and the corresponding air velocities are important, particularly when registers are located high on side walls and a long throw is required. Register sizes should be selected from tables in appendix M. Warm air may also be delivered satisfactorily through ceiling outlets of the diffusing type. Manufacturer's recommendations as to the sizing and location of these diffusers should be followed. Forced-warm-air furnaces are usually rated at a given bonnet temperature and total air throughout. This total air delivery should be maintained through proper design and installation of the duct system to ensure maximum furnace output. Due to duct heat losses, air delivery temperatures at the registers will be lower than the bonnet temperature, and the temperature difference will vary with the distance from the bonnet to the register. Since the total air requirement of a given space depends on the temperature of the air delivered to that space, these temperature drops must be taken into consideration in determining the air requirements of each room. This can be done by the use of the tables in appendix M, which gives required air quantities for various bonnet temperatures and varying duct lengths. Air is circulated from the warm air furnace through a supply duct system to the space to be heated and back again through a return duct system. To delivery the required air quantities, ducts must be of such size that, for each room, the total resistance of the supply duct and register plus the total resistance of the return duct and grille are within the available external pressure rating of the furnace fan. The external resistance which the fan of a warm air furnace is capable of meeting is stated in the furnace specifications. It is usually 0.2 of an inch water column. When air distribution systems are made up of assembled parts, fan, filters, heating coils, and the like, other duct resistance losses may be used and the fan and motor selected of sufficient size to overcome this loss. The overall resistance of a duct system is made up of the resistance of the registers and grilles, shown in tables in appendix M, the frictional resistance of straight duct, and the resistance of the various fittings. Typical fittings and their resistances in equiva-

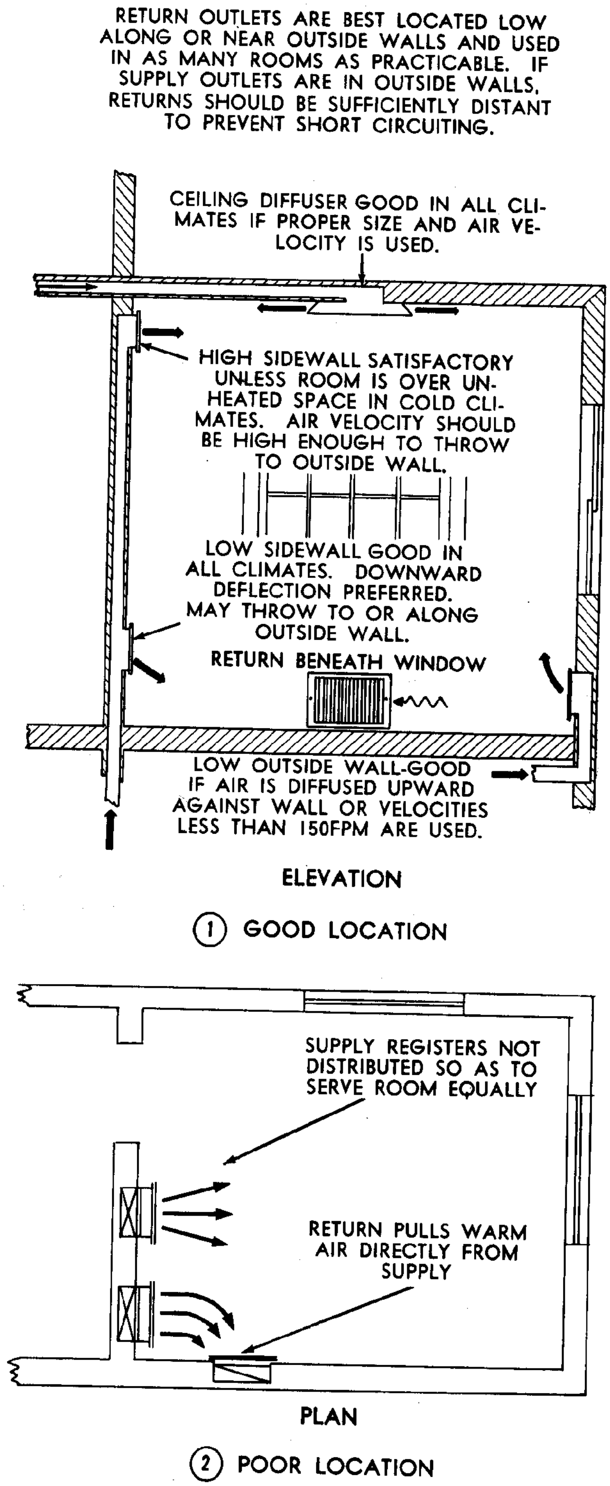


Figure 5–24. Supply and return grille location, forced-air system

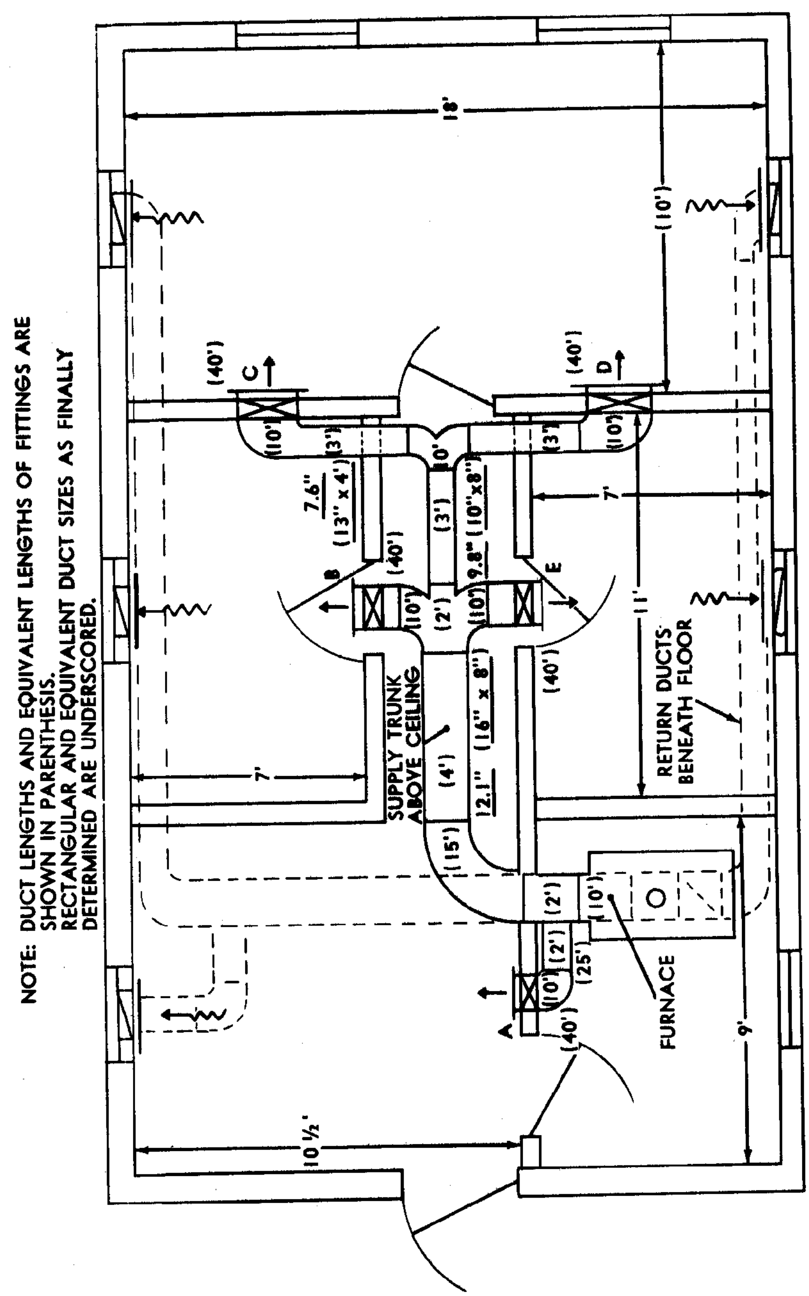


Figure 5-25. Layout for typical forced-warm-air system.

Register (1)	Heat loss (B.t.u./hr.) (2)	Req. c.f.m.[a] per 1,000 B.t.u. table M-3 (3)	Total req. c.f.m. (2) × (3) ÷ 1,000 (4)	Free Area of register sq. in. table M-1 (5)	Press. loss at register table M-1 (6)	Allowable duct loss [b] (7)	Equivalent duct length [c] (8)	Allowable loss per 100′ (7) / (8) × 100′ (9)
A	14,400	14.6	210	105	.01″	.09″	88′	.102″
B or E	10,500	15.1	159	86	.01″	.09″	81′	.111″
C or D	[d] $\frac{24,000}{2}$	15.7	189	95	.01″	.09″	99′	.091″

[a] Cubic feet per minute.
[b] Total supply system loss (taken as one half of total) less register loss from column 6.
[c] Linear length plus equivalent length of fittings from figure M-1 as shown in figure 5-25.
[d] Each register serves half of total room heat loss of 14,000 B.t.u./hr.

Figure 5-25—Continued.

lent lengths of straight duct are given in appendix M. To design a forced-warm-air duct system, proceed as follows:

(1) Calculate the heat loss of each room to be heated in accordance with paragraphs 2-2 through 2-10.

(2) Locate all supply and return registers or grilles on the floor plan (fig. 5-25) and lay out the proposed duct system showing the types of fittings to be used. Indicate the actual and equivalent length of each branch from bonnet to register using the tables in appendix M. Using the rated bonnet temperature and the tables, determine the air volume to be delivered through each register. Select corresponding air volumes for each return grille making certain that the total quantity of air return equals the toal quantity supplied.

(3) Select proper register sizes from the tables so that the necessary throw is produced for the air volume handled. Note pressure losses.

(4) Determine the maximum allowable supply duct loss by subtracting the register loss for each branch from the design pressure drop for the supply system. Select the duct run with the greatest eqivialent length, and divide the allowable duct resistance by this length to get the permissible drop per foot. Using the friction loss chart, the chart of rectangular equivalents of round ducts, and the allowable friction loss per 100 feet as guides, select sizes for each part of the supply duct system. Air velocity should increase progressively with each change in duct size from the registers to the conditioner outlet if possible. This will minimize losses due to turbulence resulting from abrupt changes in air velocity.

(5) Select duct sizes for the other supply runs in a similar manner so that the total resistance of each run does not exceed the established resistance of the supply system.

(6) Design return system in a similar manner using a total resistance which, when added to the total resistance of the supply system, will not exceed the total available pressure drop as the fan outlet. Provide dampers in each supply and return duct branch to permit balancing to correct for any inadequacies in design or to increase resistance in those short runs which may have been oversized for purposes of simplicity.

(7) *Example:* Design of the supply duct system shown in the layout diagram of figure 5-25 is based on a bonnet air temperature of 140° F., a total pressure drop of 0.2-inch water column for supply and return heat losses as shown in column (2) in the table shown in figure 5-25. The allowable pressure drop of 0.091 inch per 100 feet for registers C and D is the lowest and determines the basis of design for the system. Duct sizes based on this drop are selected from both figure M-2 and table M-1 as shown in figure 5-25. The return system is designed similarly.

c. Warm Air Perimeter Heating. Buildings on concrete slabs on the ground are hard to make comfortable because of cold floors. A satisfactory method of meeting this problem is the perimeter system. This system discharges air vertically along outside walls to overcome heat losses at these points. Heat loss from the

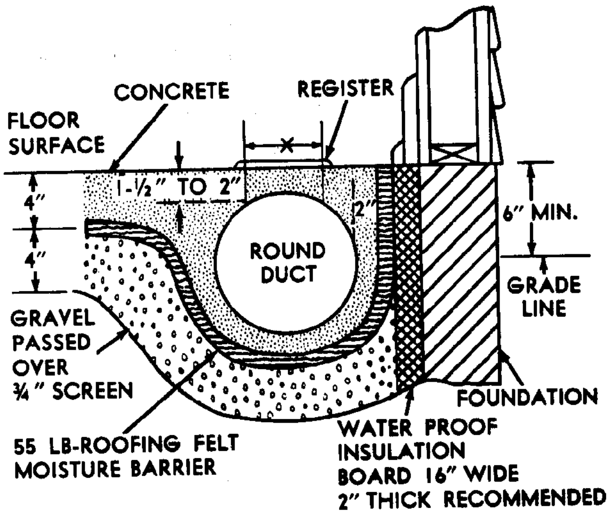


Figure 5-26. Cross-section of perimeter system.

duct comprising the perimeter loop also heats the outer edge of the concrete slab. To keep edge heat loss to a minimum, it is important that edge insulation is used (fig. 5-26). This type of system promotes the use of floor type registers to blanket the outside walls with air to counteract the heat loss from the building at the greatest point of loss (fig. 5-25). Because the supply air is introduced with sufficient quantity and velocity to blanket the exposed wall and from floor to ceiling height, either low or high returns are taken from the heated area. Counterflow type warm air heating units using forced circulation of air are usually used in such installations. Conventional units with suitable duct adaptors may be used in larger sizes where counterflow units are not made.

(1) *Duct layout.* A typical perimeter loop duct layout is pictured in figure 5-27. Outlets are located to supply air at the points of greatest heat loss such as under windows, long spans of wall or next to doors. Based on the total heat loss figure obtained in chapter 2, the unit is selected to supply an output capacity equal to the heat load calculated plus 10 percent loss in the duct distribution system. Using the heat output of the unit selected, number of cubic feet per minute (c.f.m.) through the unit required to satisfy the unit requirement is calculated using;

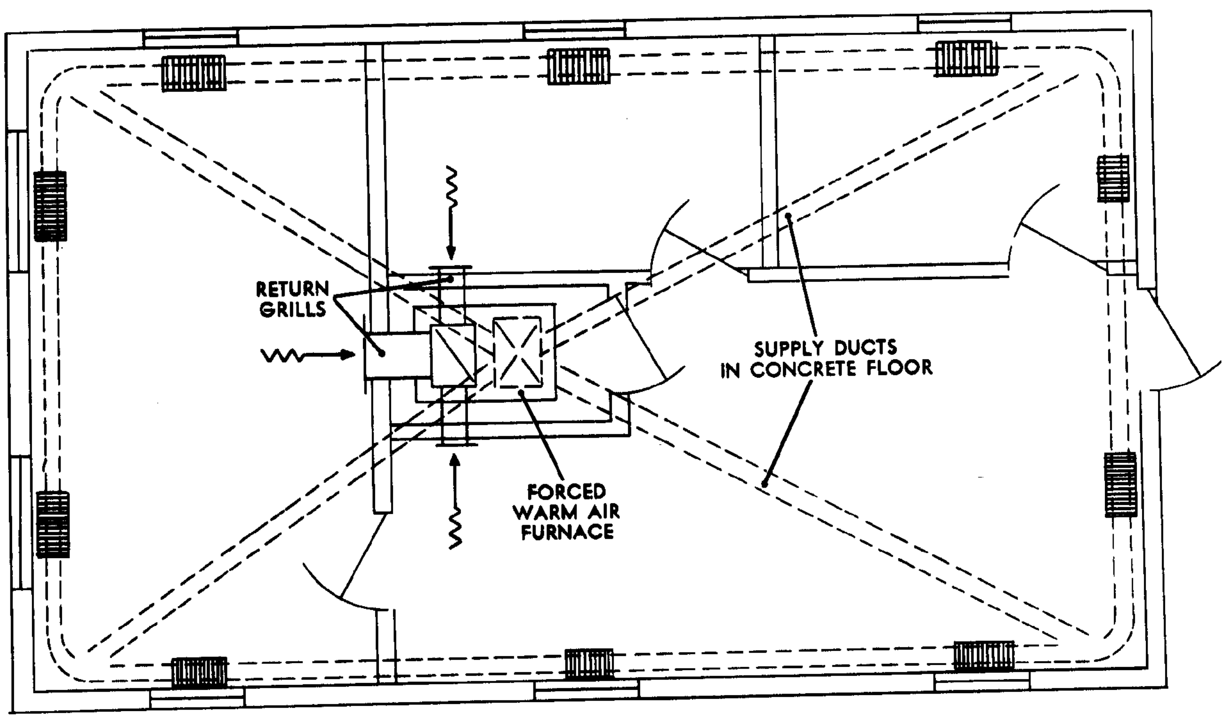


Figure 5-27. Layout of perimeter system.

$$\text{c.f.m.} = \frac{\text{B.t.u. OUTPUT}}{\text{T.D.} \times \text{K.}}$$

B.t.u. Output = Unit output in B.t.u. per hour.
T.D. = Temperature rise of air through unit.
K = A constant for converting weight of air to volume and hours to minutes.

The accepted practice in industry today is to use 80° temperature rise of the air and 1.08 as the constant. After determining the total c.f.m. for the unit to design the perimeter loop system, proceed as follows:

(*a*) Locate the perimeter loop duct on the plan.

(*b*) Locate the outlets on the plan. Principle rooms such as living and dining rooms with two or more exposed walls should have at least two outlets, one along each wall below the windows. For extended glass areas, such as long picture windows, two or more outlets may be required.

(*c*) Locate the feeder ducts in the plan by dividing the total c.f.m. required by the unit by 175 c.f.m. (the capacity of the average feeder is 175 c.f.m.). This probable number of feeders may have to be changed later in the design procedure to meet the requirement listed in the second and third paragraphs of this section. Locate the first feeder duct so it will connect to the perimeter loop near the corner of the room having the most glass surface or the largest wall spans. This is the best way to handle this area having the greatest heat loss. On the plan locate the points where other feeders are to connect to the loop duct according to the following principles: the distance between points where the feeders connect with the loop should never be more than 35 feet; there should not be more than three outlets in any section of the perimeter duct between any two feeders; no feeder should connect to the perimeter loop at a point less than 18 inches from the nearest outlet; no outlet should be more than 15 feet from the nearest feeder; if the distance between two adjacent outlets along a section of perimeter duct between feeders is more than 20 feet, provide an additional feeder duct between these outlets; and outlet should never be installed in a feeder duct.

(*d*) After location of the feeder ducts on the plan according to the above requirements, divide the total c.f.m. requirement of the unit by the total number of feeder ducts. This will result in the average c.f.m. per duct.

(*e*) Measure the length of the feeder ducts to obtain the length of the longest one. Using this length and the average c.f.m., obtan the size of the feeder ducts and perimeter loop from table 5-1.

Table 5-1. Feeder Duct and Perimeter Loop Sizes

Average c.f.m.	Length of Feeder in Feet	
Per Feeder	0-15 Feet	16-30 Feet
0- 93	6″	6″
94-104	6″	7″
105-127	7″	7″
128-139	7″	8″
140-151	7″	8″
151-197	8″	8″

(*f*) Count the total number of outlets laid out on the plan and divide this number into the c.f.m. of air to satisfy the unit requirement. This will result in the c.f.m. per outlet. Using this c.f.m. quantity, the height of the ceiling of the room (throw), and the width of the air pattern desired (spread), select the register sizes from appropriate manufacturers' catalogues.

(2) *Return air system.* The return air system should be as short and of as low resistance as possible. High wall or ceiling outlets are used for best circulation of air throughout the occupied area. Usually a drop ceiling in a center hall is used as the return air plenum. For minimum blower noise transmission the return duct system should be designed with a 90° turn (preferably two turns) in the air flow from the return air grill to the unit blower assembly. Do not depend on the air filters to act as sound deadeners.

Section III. CONTROL

5-11. Purpose

Controls for warm air systems are of two types: operating controls which actuate and regulate the operation of equipment so that it meets the heating requirements of the space it serves and safety controls which protect the equipment and the building in which it is installed from damage due to faulty operation. Operating controls both provide heat when required and reduce or prevent heating when it is not required, saving fuel. Because the temperature of air leaving any space heater or furnace may climb to a dangerous point if the total air circulation is restricted, and because this air may pass close to combustible material, means must be provided for limiting outlet air temperatures under any operating condition.

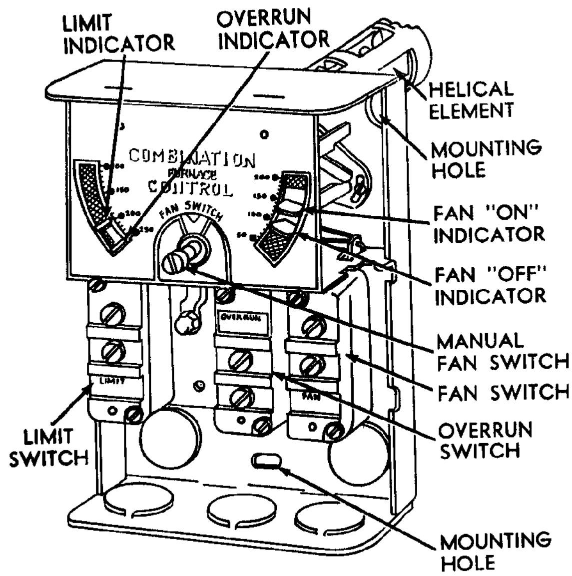
5-12. Operating Controls

a. Thermostat. The types of room thermostats used with warm air systems and the principles of their aplication and location are similar to those applying to steam heating systems (para 3-19). Space heaters, because they are located in the occupied space, are frequently controlled manually. Space heaters can also be controlled by a remote thermostat, and some are equipped with a thermostat mounted on the heater, located so that it measures the temperature of room air returning to the heater.

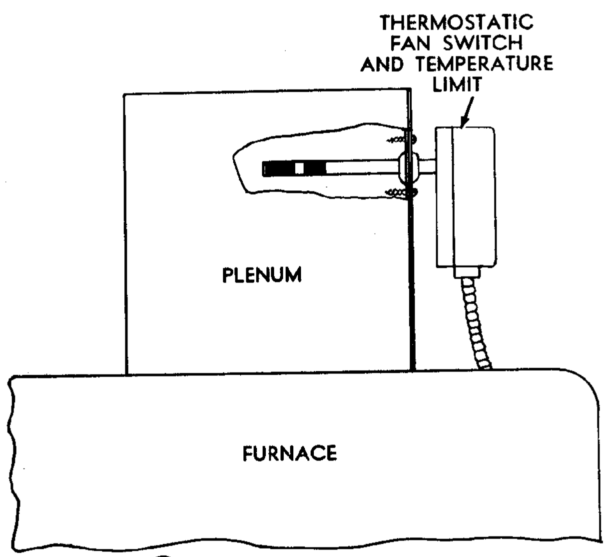
b. Fan Control. Space heaters and furnaces equipped with air-circulating fans require a thermostatic fan switch to prevent the fan from distributing cool air, causing drafts before the furnace has heated to operating temperature. The fan switch also serves to keep the fan in operation after the burner has been shut off until all usable heat has been removed from the furnace. The fan control switch, shown in (1), figure 5-28, may be a subassembly of the furnace or may require location by the installer. This control is installed (when not a subassembly) in the air outlet duct connection or plenum close to the unit so that it will always receive warm air by gravity operation before the fan is in operation, but not so close to the heating section that it will be seriously affected by heat radiated from the heating unit ((2), fig. 5-28).

5-13. Safety Control

High-temperature-limit controls may be provided as part of the heating equipment or may require location in the outlet duct by the installer. Requirements for their location are the same as those for thermostatic fan controls. The limit control may be combined with the fan switch ((1), fig. 5-28) in a single instrument. High-temperature-limit controls are set at 200° F. to limit air temperatures to a safe figure.



(1) COVER REMOVED



(2) INSTALLED IN PLENUM

Figure 5-28. Combination fan switch and limit control.

Section IV. INSTALLATION

5-14. Erection of Equipment

a. Space Heaters. Space heaters of all types must be installed with strict observance of necessary clearances from combustible construction. Required clearances for gas- and oil-fired heaters are included in manufacturers' specifications. The required clearances for coal-fired heaters are shown in figure 5-29. Flue pipe is secured to the heater at each joint with one or more sheet metal screws to insure rigidity. A clearance of at least 18 inches is maintained between the metal flue pipe and any inflammable material. When oil-fired space heaters are used, a balanced draft regulator should be installed in the flue pipe. Further information can be found in TM 5-646.

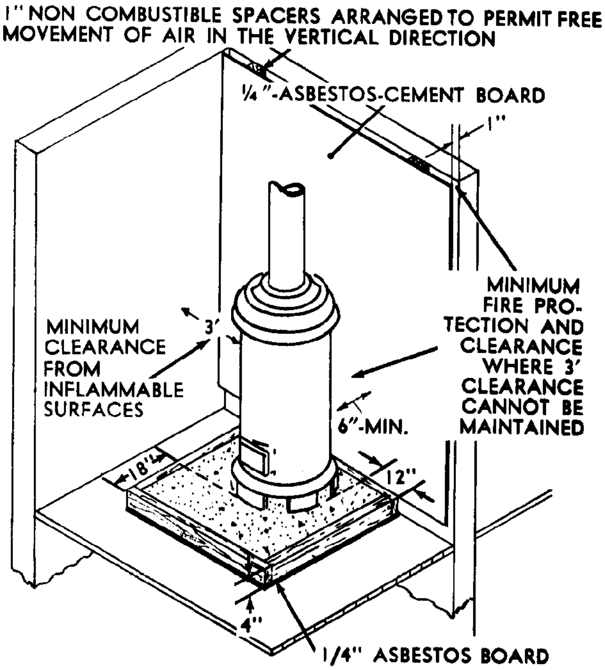


Figure 5-29. Details of space heater installation.

b. Warm Air Furnaces. Oil- and gas-fired warm-air furnaces of the newer types, particularly in the smaller sizes, are shipped completely assembled and require little if any erection in the field. Coal-fired furnaces are usually shipped knocked down and require field assembly. As there are many types and makes of furnaces, follow the manufacturer's detailed assembly instructions in each case. Cast iron combustion chambers and radiators shipped in two or more pieces must be assembled carefully, and all joints must be sealed with liberal quantities of furnace cement. Asbestos rope packing is furnished and specified for certain applications.

***Caution:* If all joints are not sealed tightly, there is a chance that combustion gases, which may include carbon monoxide, can leak into the circulating air stream and be distributed to living spaces.**

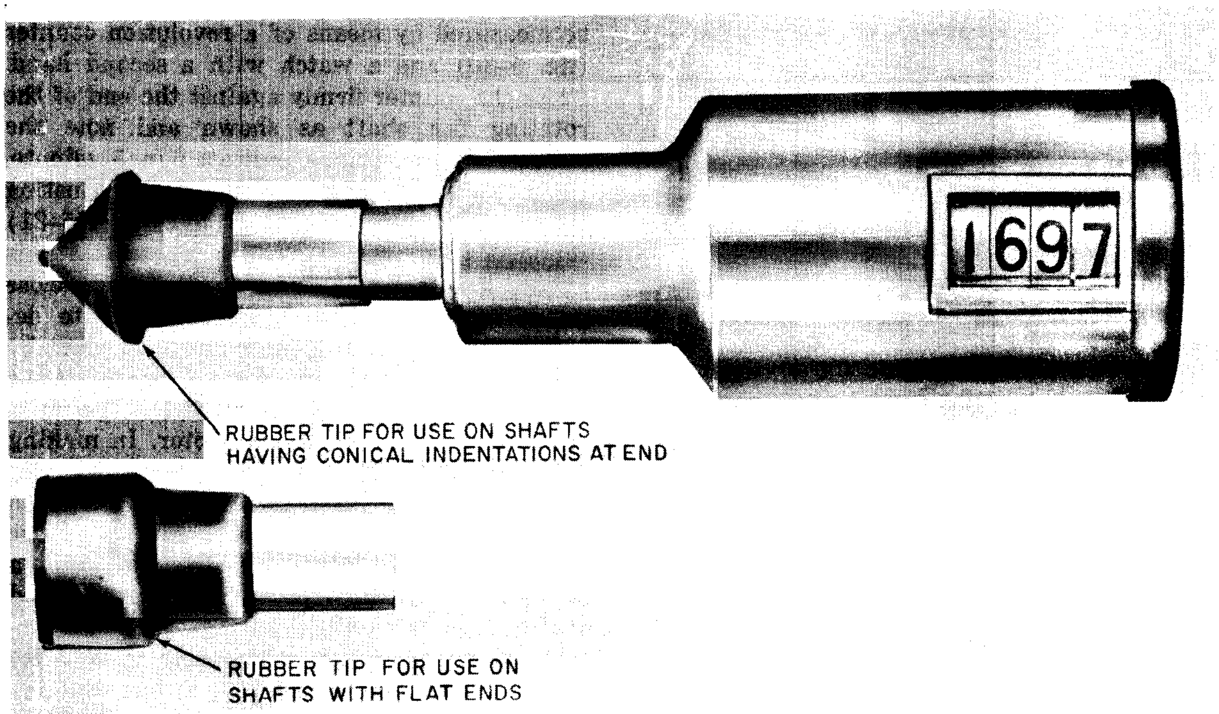
Required clearances from construction vary from 0 to 3 feet for various units. Clearances are given in manufacturers' specifications and should be followed. At least a 2-foot clearance is provided for access for service and repair on those sides of the furnace where such access is required.

5-15. Air Ducts

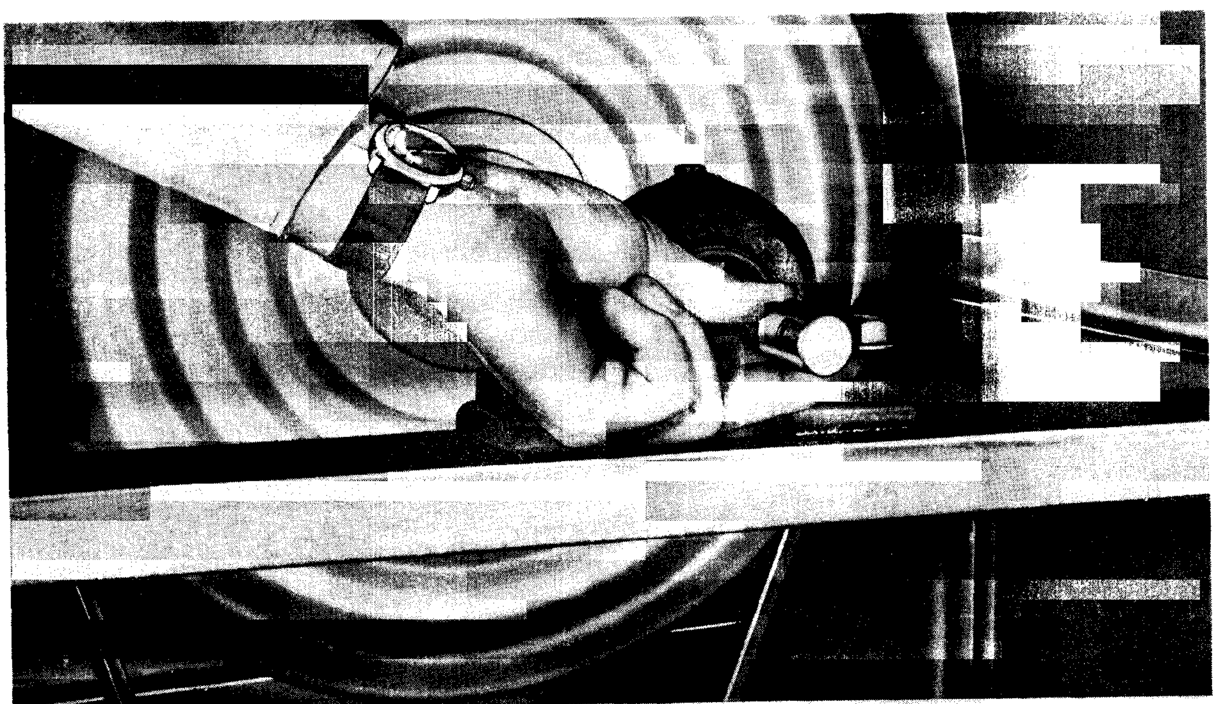
The installation of sheet metal air ducts is covered in detail in chapters 10 and 11. This work is specialized and should only be done by qualified sheet metal mechanics. Tinsmiths' Equipment Set No. 1 and Sheet Metal Working Equipment Set Nos. 1 and 2 are required.

5-16. Adjustment

Almost every warm air system will require adjustment or balancing of air flow to the various outlets before satisfactory heat distribution can be obtained. This balancing is accomplished by the adjustment of dampers located in the duct branches or in the stack heads behind the registers. The first step in balancing a forced-air system is to make certain that the total air passing through the unit is at least equal to the quantity specified. This can be done with greatest ease and accuracy by the indirect method of measuring the air temperature rise through the furnace with the furnace in operation. Many furnaces are designed to operate at a specified temperature rise, usually 100° F. Where air delivery and not tem-



(1) REVOLUTION COUNTER



(2) USE OF REVOLUTION COUNTER

Figure 5-30. Measuring fan speed.

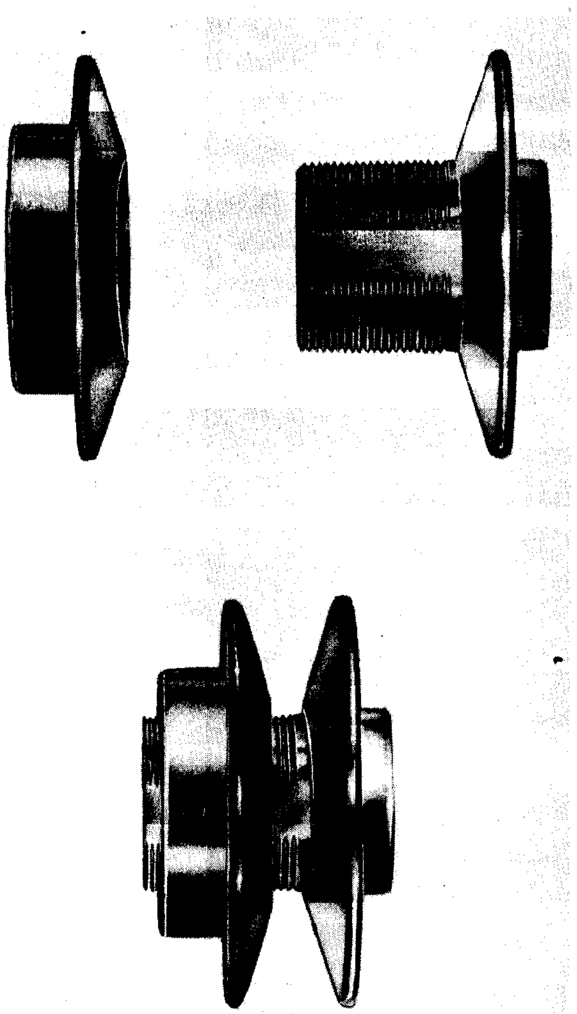


Figure 5-31. Variable diameter motor pulley.

perature rise is specified, the total air delivery can be calculated from the measured temperature rise by means of the formula:

$$Q = \frac{I \times E}{1.08\ (T_1 - T_2)}$$

where Q is the total air delivery in cubic feet per minute; I is the rate of fuel input in B.t.u. per hour; E is the furnace efficiency, which can be taken at 80 percent for gas or 70 percent for oil; T_1 is the average temperature of the air leaving the furnace; and T_2 is the average temperature of the air entering the furnace. The total air delivery can be changed if necessary by changing the fan speed. Fan speed can be measured by means of a revolution counter (fig. 5-30) and a watch with a second hand. Press the counter firmly against the end of the rotating fan shaft as shown and note the number of revolutions indicated in 1 minute, r.p.m. Fan speed can be changed by adjusting the variable diameter motor pulley (fig. 5-31) supplied with most furnaces. To adjust this pulley, loosen setscrew in outer flange, close pulley to increase fan speed, or open to decrease speed. Lock the outer flange in place by tightening setscrew on flat of pulley. Care should be taken not to operate the fan at a speed that will overload the motor. In making fan adjustment, it must be remembered that total air delivery varies in direct proportion to the speed of centrifugal fans. The thermostatic fan switch should be set to operate at as low a temperature as possible without causing cold drafts. Low fan switch settings give long periods of fan operation which help to equalize temperature distribution. The differential between cut-on and cutoff temperatures should be no greater than required to prevent the fan from cycling on and off while the furnace is heating up. Fan switch settings of 100° F. ON and 115° F. OFF should prove satisfactory for most installations where required air volumes and register velocities are known. Time may be saved by measuring the air velocity at each supply and return register, with all dampers open, by means of an air-flow measuring instrument (fig. 5-32). Dampers can then be adjusted where required to give design air velocities at each outlet. Final adjustments of both gravity and forced-air systems should be checked by measuring temperatures in all rooms under load conditions and any necessary adjustments made to equalize room temperatures.

5-17. Maintenance

Details of maintenance of warm air systems are covered in inspection and preventive maintenance service manuals, TM 5-643 covering warm air furnaces and TM 5-647 covering space heaters. In addition, special attention should be given to the following:

a. Cleaning of Filters. Where air filters are provided with warm air systems, the filters

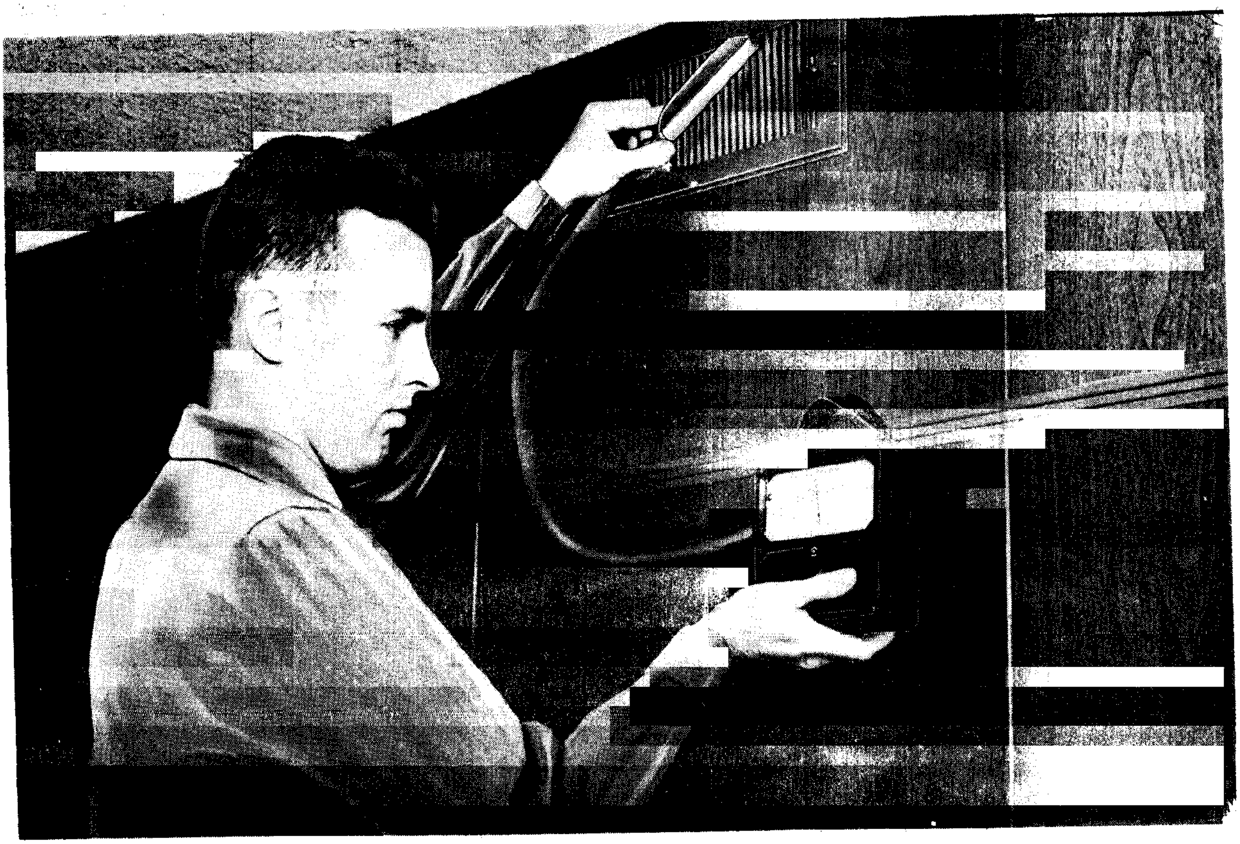


Figure 5-32. Measuring air flow with a vane anemometer.

must be inspected periodically and cleaned or replaced whenever necessary. Dirty filters reduce air flow, impair heating performance, and increase fuel consumption. Filters should be inspected at least once a week. Methods of cleaning filters are discussed in paragraph 7-8.

b. Oiling of Fans and Motors. Fan and motor bearings require regular oiling at least twice each heating season. Bearings are usually fitted with oil cups (fig. 5-33) and these cups are filled with the proper oil as prescribed by the manufacturer whenever necessary. Be careful not to over-oil motor bearings.

c. Belt Adjustment. All motors are mounted on adjustable bases to permit adjustment of blower belt tension. Locate the motors so that there is from 1½ to 2½ inches of play in the belt (fig. 5-34). Make certain that both pulley wheels are in the same plane and the V-belt does not rub on the side of a pulley.

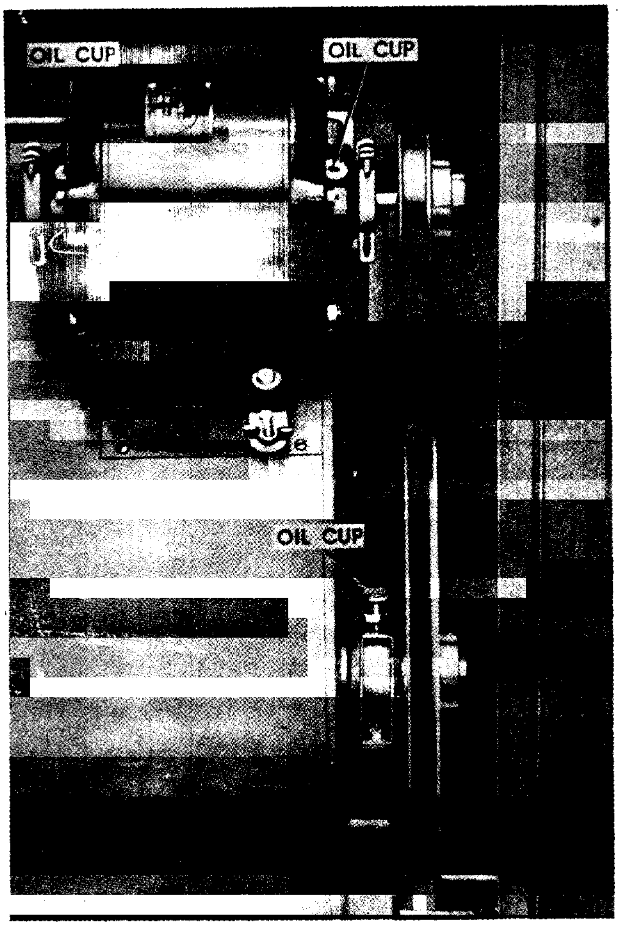
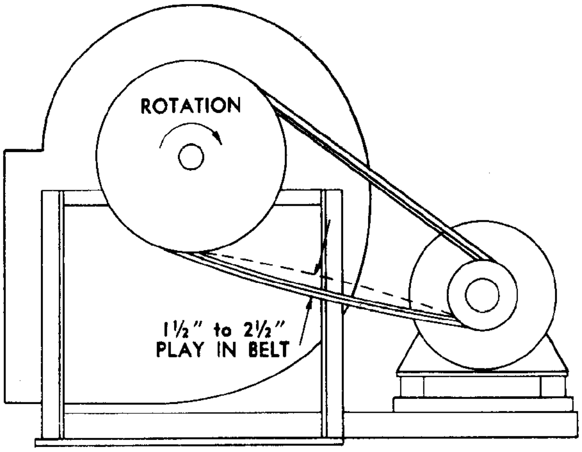


Figure 5-33. Oil cups on fan and motor.



BLOWER BELT TENSION

Figure 5-34. Fan belt adjustment.